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(In preparation.) The following have already appeared in the psychological periodicals:

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THE INFLUENCE OF CAFFEIN ON MENTAL AND MOTOR EFFICIENCY

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EDITED BY

R. S. WOODWORTH

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PREFACE

In the spring of 1911 the writer was called on by the Coca-Cola Company, of Atlanta, Ga., for an opinion as to the influence of caffein on mental and motor processes. In the absence of adequate reliable data (see discussion of previous investigations) it seemed necessary to conduct a set of careful experiments before any opinion could be rendered with either fairness or certainty. Such an investigation was made possible by an appropriation by the Coca-Cola Company sufficient to cover all the expenses of the experiments. A later appropriation made possible the publication of this monograph, which presents in full the results of that investigation, a preliminary oral report of which was made by the writer in the U. S. Court at Chattanooga in March, 1911.

The writer is well aware of a popular tendency to discredit the results of investigations financed by commercial firms, especially if such concerns are likely to be either directly or indirectly interested in the outcome of the experiments. He is also aware of a similar human impulse at once to attribute interpretative bias to the investigator whose labors are supported and made possible by the financial aid of a business corporation, and hence do not represent a vicarious sacrifice of time and effort on his own part.

From the point of view of the immediate data any such bias can easily be avoided by having the measurements made and recorded by assistants who know neither the experimental conditions under which the records are being made nor the direction in which the facts may be pointing. If these data are then presented in full they may receive independent interpretation by any one who is inclined to take the pains to examine them. Such conditions were adhered to throughout the experiments to be reported here, and the immediate data are given in full. Thus in no case did any assistant know whether the measurement being made was a caffein record or a control record (see chapter on method), and separate tables are given which present all these records.

But the monograph would be relatively useless were no attempt made to interpret the data. The writer has therefore given the conclusions based on his own careful study of the records, and these conclusions are, to the best of his ability, free from all suggestion of prejudice or bias. While he was compensated for the time given to

the experiments themselves and to the preliminary oral report, the considerable labor involved in preparing the results for publication is entirely his own contribution, and was undertaken on his own initiative. The invitation to direct such an investigation provided opportunity for a most valuable addition to scientific knowledge of the effects of the substance specifically studied; for a careful examination into the value of various sorts of tests for the purposes of such study; and for the accumulation of a great mass of data on a variety of problems of intense psychological interest. To have refused this opportunity to make a useful contribution to knowledge, and to hesitate to interpret the results of the study, simply through fear of the suspicion of bias, would have been nothing less than an evasion of scientific duty.

In the light of these statements the reader must place his own estimate on the ability of the writer to free his interpretation of all suggestion of bias. The complete data are given. They have been compared from several points of view and by various methods of computation. The conditions of each experiment are explicitly stated. Conclusions can thus be checked up without difficulty by reference to the records themselves, or somewhat more inconveniently by a repetition of the experiments reported.

H. L. HOLLINGWORTH.

COLUMBIA UNIVERSITY.

CONTENTS

THE INFLUENCE OF CAFFEIN ON MENTAL AND MOTOR EFFICIENCY

CHAPTER I

Summary of Previous Investigations

The literature on the influence of caffein on fatigue has been so recently summarized and the unreliability of the older experiments so clearly pointed out by Rivers[1] that it seems superfluous to go over the field again in any great detail. Hence the present chapter will give only a brief summary of the most important researches which have had as their object the determination of the influence of caffein on mental and motor processes. No attempt will be made to discuss the physiological effects of the drug, since such summaries can be found in any of the standard works on pharmacology.

In 1892 increase in the force of muscular contractions was demonstrated by De Sarlo and Bernardini[2] for caffein and by Kraepelin for tea. These investigators used the dynamometer as a measure of the force of contraction. Most of the subsequent work on motor processes has been by the ergographic method. Ugolino Mosso,[3] Koch,[4] Rossi,[5] Sobieranski,[6] Hoch and Kraepelin,[7] Destree,[8] Benedicenti,[9] Schumberg,[10] Hellsten,[11] and Joteyko[12] have all demonstrated the stimulating effect of caffein on ergographic performance, the drug being administered in such various forms as caffein, tea, coffee, kola, mate, guarana and theobromine. Only one investigation of those reported by Rivers failed to find an appreciable effect, that

[1] W. H. R. Rivers, "The Influence of Alcohol and Other Drugs on Fatigue."
[2] *Revista sper. di Freniatria*, 18, 1.
[3] *Archiv ital. de Biol.*, 19, 241, 1893.
[4] Inaug. Diss., Marburg, 1894.
[5] *Revista sper. di Freniatria*, 20, 458, 1894.
[6] *Centralbl. f. Physiol.*, 10, 126, 1896.
[7] *Psychol. Arbeit.*, 1, 378, 1896.
[8] *Journal Med. de Bruxelles*, 1897.
[9] *Moleschott's Untersuchungen*, 16, 170, 1899.
[10] *Archiv f. Anat. u. Physiol.* (Physiol. Abth.), Suppl. Bd., 1899, 289.
[11] *Skand. Arch. f. Physiol.*, 16, 197, 1904.
[12] *Travaux du Lab. de Physiol. Inst. Solvay.*, 6, 361, 1904.

of Oseretzkowsky and Kraepelin.[13] Feré[14] affirms that the effect is only an acceleration of fatigue.

Although there is general agreement here as to the presence of stimulation there is some dispute as to whether only the height of the contractions or their number or both are affected. The quantitative results have also varied considerably, as might be expected under such great diversity of methods as has been followed. Carefully controlled experiments by Rivers and Webber[15] "confirm in general the conclusion reached by all previous workers that caffein stimulates the capacity for muscular work; and it is clear that this increase is not due to the various psychical factors of interest, sensory stimulation and suggestion which the experiments were especially designed to exclude. The greatest increase . . . falls, however, far short of that described by some previous workers such as Mosso, and it is probable that part of the effect described by these workers was due to the factors in question." Recent experiments by H. C. Wood, Jr.,[16] on the influence of caffein on isolated frog muscle bear in the same direction.

Investigations of mental processes under the influence of caffein have been much less frequent. Dietl and Vintschgau[17] found a striking and prolonged acceleration in the simple reaction time 20–25 minutes after drinking two cups of black coffee. Dehio[18] concluded, on the basis of inadequately controlled experiments, that coffee and tea did not exert any considerable effect on simple reaction times, produced a very slight acceleration of choice reaction times, but stimulated to a striking degree word reactions and association reactions. The effect began in about 15 minutes after the drink and lasted longer in the case of the association reactions than in any other case (over 1 hr.). The acceleration is said to have been sometimes followed by a retardation, but the different tests did not agree on this point and it is suggested that the retardation is only a normal fatigue phenomenon. These results are, however, quite unreliable, for the tests were often made on the evening of days on which ether, chloroform or alcohol had been taken in the morning, neither control doses nor control subjects were used, and no normal records were taken on the subjects tested. The tests, moreover, lasted for only a

[13] *Psychol. Arbeit.*, 3, 617, 1901.

[14] *C. R. de la Soc. de Biol. Paris*, 593–627, 1901.

[15] W. H. R. Rivers, *op. cit.*, p. 38.

[16] Paper before Section on Medicine, College of Physicians of Philadelphia.

[17] "Das Verhalten der physiologischen Reactionszeit unter dem Einfluss von Morphium, Kaffee und Wein," *Pflügers Archiv*, 16, 316, 1877.

[18] "Untersuchungen über den Einfluss des Caffeins und Thees auf die Dauer einfacher psychologischer Vorgänge," Diss., Dorpat, 1887.

short time, the variations found were quite within the normal range of variability for such limited number of observations as were made; no attempt was made to eliminate practise or fatigue; and no allowance was made for sensory stimulation, excitement or interest.

Kraepelin's[19] earlier attempts to retest Dehio's results on association times are equally useless, since the results are affected by a practise fall of 50 per cent., the tests were performed at different times of day, on days irregularly interspersed among alcohol experiments, and the dose was not caffein in any of its pure forms, but a brew of tea, with no control doses. Kraepelin's attempt to determine the influence of tea on the *content* of the associations is similarly meaningless. In still later experiments, although by defective methods, Kraepelin found acceleration in addition, retardation in speed of memorizing digits, increase in speed of reading, but is not positive that the changes pointed out were really due to the influence of the tea. He concludes that tea facilitates the perception of external impressions (Auffassung ausserer Eindrücke) and the combination of ideas (Verbindung der Vorstellungen). The latter factor is less influenced in the case of much practised and stereotyped associations. The increase in work Kraepelin believes to be due entirely to these two changes, and supposes that no acceleration of simple motor processes (Auslösung der Muskelbewegung) takes place. The increased force of contraction in dynamometric tests, which persists for a shorter time than the above influences, is explained as due to the direct peripheral action of the caffein content on the irritability of muscle tissue.[20]

Kraepelin concludes, finally (p. 224):

"The picture of the tea influence which we have thus secured agrees in all essential points with the experiences of daily life. We know that tea and coffee increase our mental efficiency in a definite way, and we use these as a means of overcoming mental fatigue. . . . In the morning these drinks remove the last traces of sleepiness and in the evening when we still have intellectual tasks to dispose of they aid in keeping us awake. In large amounts and in the case of sensitive persons their ingestion delays sleep. On the other hand, the motor disturbance, the tendency to boisterous and silly conduct, the peculiar euphoria and the exaggerated feeling of strength, characteristic of alcoholic intoxication, never result from the use of tea and coffee. In their places ensues a greater briskness and clearness of thought. . . . But secondary fatigue is either entirely absent or is very slight, whereas in the case of alcohol it follows quickly and inevitably."

[19] E. Kraepelin, "Ueber die Beeinflüssung einfacher psychischer Vorgänge durch einige Arzneimittel," pp. 107–148, 216–225.

[20] See Kobert, "Uber den Einfluss verschiedener pharmakologischer Agentien auf die Muskelsubstanz," *Archiv f. experimentelle Pathologie u. Pharmakologie*, 15, 63.

In a still later piece of work Kraepelin and Hoch[21] investigated the influence, on performance in the addition test and in the production of ergograms, of the two chief constituents of tea—the caffein and the essential oils. Both the caffein and the oils were found to exert a favorable influence, which was greater in the case of the caffein. Paraguay tea had similar effects, which are attributed to its caffein content.

Ach[22] tested choice reactions and the speed and accuracy of the perception of words and nonsense syllables, in the case of two subjects, after .2 and .5 grams of caffein (whether alkaloid or citrated is not stated) administered in gelatine capsule. Control doses of common cooking salt were used on two days and caffein on three days. Control tests were also made before the doses on the caffein days. The results showed caffein to affect chiefly the accuracy and the time of perception, the influence showing itself in the form of improvement in both speed and number of mistakes. The choice reaction times show no clear effect, and the results, as a whole, are complicated by practise effect and by a considerable separation of two of the days from the other three. The caffein effect is said to begin about 20 minutes after the dose and to be measurably present after more than one and a half hours. There were indications that the caffein influence was stronger under conditions of fatigue.

Rivers[23] seems to have been the first to appreciate fully the genuine and practical importance of thoroughly controlling the psychological factors that are likely to play a rôle in such experiments. His analysis of these factors is pointed out in detail in the following chapter. Attempting to eliminate, by properly controlled procedure, all such factors as knowledge of the character of the dose, sensory stimulation, suggestion, excitement, interest and practise, Rivers investigated both motor and mental efficiency, with special reference to the course of fatigue. His results on force of movement, secured by the ergographic method, have already been quoted. The experiments involving more distinctly mental factors (chiefly perception and coordination) were on typewriting and on McDougall's "accuracy of aim" test. Caffein (.3 gram citrated), was found to increase the speed of performance in typewriting, but to have no influence on the accuracy. In the "accuracy of aim" test the caffein days were found to be superior to the control days. The chief objections to Rivers' experiments are the limited number of subjects (only him-

[21] *Psychol. Arbeit.*, 1, 431, 1896.

[22] N. Ach, "Uber die Beinflüssung der Auffassunsfähigkeit durch einige Arzneimittel," *Psychol. Arbeit.*, 203–289, 1901.

[23] Rivers, *op. cit.*

self and a fellow worker), the insufficient length of time over which the effect of the dose was traced, and the small number of tests employed. His work is especially valuable for its emphasis on experimental technique in administering the doses.

Rivers' general conclusion is as follows:

"The general practical conclusion to be drawn from the experiments which I have recorded, and from those of previous workers, is that caffein increases the capacity for both muscular and mental work, this stimulating action persisting for a considerable time after the substance has been taken without there being any evidence, with moderate doses, of reaction leading to diminished capacity for work, the substance thus really diminishing and not merely obscuring the effects of fatigue. The results of one experiment, however, point unmistakably to the conclusion that, when taken in excess, the stimulating action may be so transitory and followed by so great a decrease that it may legitimately be spoken of as an accelerator of fatigue. . . . The experiment suggests strongly that caffein is a dangerous remedy as a stimulant in cases of prolonged fatigue, or of that enhanced tendency to fatigue which is the characteristic feature of neurasthenia" (p. 50).

Langfeld,[24] in an investigation of the influence of caffein on "suppression with negative instruction," has recently reported that "caffein caused a decrease in the reaction time for association, and showed no appreciable effect upon the suppression or accuracy of reproduction."

[24] *Psychological Review*, 18, No. 6, 424, November, 1911.

CHAPTER II

The Purpose and Method of the Experiment

Previous experiments on the influence of caffein on psychological processes have been limited to a few tests of a very limited number of individuals, and have not been carried out under sufficiently rigorous experimental conditions. The processes tested in a given experiment have been few in number, the subjects have not been on a practise level of performance, the size of the dose has not been varied over any considerable range, nor has the drug been administered unmixed with other substances which have in themselves a measurable influence on the processes tested, nor has the caffein influence been traced for any considerable length of time. Hence in making the present elaborate series of experiments the following five chief purposes were held in mind. Of these five topics the first four can be appropriately discussed in the present monograph. The fifth must be left for a future series of papers.

Purposes

1. To determine both qualitatively and quantitatively the effect of caffein on a wide range of mental and motor processes, by studying the performance of a considerable number of individuals for a long period of time, under controlled conditions.

2. To study the way in which this influence is modified by such factors as the age, sex, weight, idiosyncracy and previous caffein habits of the subjects, and the degree to which it depends on the amount of the dose and the time and conditions of its administration.

3. To investigate the influence of caffein on the general health, on the quality and amount of sleep, and on the food habits of the individuals tested.

4. To inquire into the value and adaptability of a considerable array of simple tests with a view to their standardization for the purposes of pharmaco-dynamic research.

5. To accumulate data on the effects of practise, fatigue, diurnal variations in efficiency, the physiological limit, individual and sex differences and various other allied topics growing out of such an extended series of tests on a large number of subjects.

Plan and Procedure

In order to reduce to a minimum distractions and disturbances to which such experiments are likely to be subjected, and to provide for the greatest convenience of the experimenters and the comfort of the subjects, a well-lighted and ventilated six-room apartment on the ground floor of a building in a quiet part of the city was rented and equipped as a special laboratory. An abundance of chairs, tables, recording materials and files was secured, and special lights, batteries and the requisite psychological apparatus installed, including two motor test boards, two Columbia chronoscopes, ten stop watches, a stethoscope, illusion weights (3 sets), test blanks and the special tests to be described later. The tests were assigned to the various rooms and each room placed in charge of a competent assistant (see page 15).

Sixteen subjects, ten men and six women, were engaged for full time for a period of 40 days, and were required to appear at the laboratory at stated times during the day or to remain there permanently as the case might be, and to submit themselves at regular intervals to the series of mental and motor tests. These subjects were to abstain from the use of all forms of caffein (coffee, tea, choclate, cocoa), alcohol, nicotine and all other drugs, as well as from soda fountain drinks containing patent syrups, except in so far as these drugs were prescribed by the director or by the medical assistant. They were also to observe regular hours of eating and sleeping and to report any unavoidable irregularities in these matters. Before beginning the experiment each subject subscribed to the following agreement:

It is Hereby Agreed

1. That I will abstain from the use in any form or quantity, of tea, coffee, tobacco, chocolate and cocoa, soda-fountain drinks containing patent syrups, alcoholic drinks (including beer) and all other such drugs, except at the prescription of the Director, so long as I shall serve as subject in this experiment.
2. That I will observe regular hours of eating and sleeping during the same period, taking my meals at the hours to be later prescribed by the Director.
3. That I will exert myself in every trial of every test to make the best and speediest record possible for me.
4. That I will conscientiously report to the medical adviser the condition of my health from day to day, along with any other items concerning which information may be desired.
5. That I will serve as subject in this experiment for as many of forty days as my assistance may be desired.
6. That I will appear regularly and promptly at the test hours.
7. That I will observe all other reasonable instructions which the Director may from time to time suggest for the good of the experiment.
8. That the failure to observe these instructions and conditions to the satis-

faction of the Director shall be deemed sufficient reason for forfeiting all compensation for any service I may have rendered up to that time and for terminating my connection with the experiment.

9. That I will if desired, at the close of the experiment, take oath before a notary public that I have lived up to the conditions of this agreement.

Signed,

The experiment as performed consists of three separate sections.

A. A series of tests covering a period of four weeks, in which all the subjects went through the tests five times a day (each time requiring about one hour) at 7:45 and 10:00 A.M. and at 12:15, 3:10 and 5:30 P.M. This arrangement left about one hour between tests, during which time the subjects were free to go about their own work or to remain in the laboratory reading, sewing, etc. During the first week, in order to allow all subjects to get perfectly adapted to the experiment and to become practised in the tests, sugar of milk doses were given to all individuals daily. After this week the caffein doses began. The subjects were then divided into four squads. To one squad (I.) consisting of four subjects, no caffein was administered throughout the experiment, but the control capsule, containing sugar of milk, was given daily. A second squad (II.) consisting of three subjects, alternated throughout the experiment, taking caffein on three days and sugar of milk on the following three days, at 10:30 A.M. This squad lunched between one and two o'clock. The caffein dose varied from one to six grains, the same amount being taken on each of a given set of three caffein days. A third squad (III.) consisting of three subjects, took caffein and sugar of milk on alternate days, at the lunch hour, the dose varying from one to six grains. Squad IV. consisting of five subjects took caffein and sugar of milk on alternate days from two and a half to three hours after lunch, which was, in these cases at 11:30 A.M. (For details concerning the character of the doses and the methods of administering them, see a later section of this chapter, p. 10.)

B. The second section, an intensive experiment of three days, was performed in order to study at close range the effect of caffein on the various processes tested, and to determine its time relations in the various cases and with the different subjects and squads. In this experiment the plan was followed of having all the subjects assemble at the laboratory at 10:00 A.M. At this hour the tests were begun and were kept up continuously for about 12 hours, except for two 45-minute periods allowed for lunch and dinner. All subjects ate at the same place at lunch and dinner of these three days, in order to eliminate variations due to differences in diet, condition of stomach, and to exercise going to and from the laboratory. The

meals were prepared and eaten in the house in which the laboratory was situated. By this means the action of the doses could be traced at close range, since all subjects returned repeatedly to the same test after having just passed through all the others in immediate succession. Fifteen records for each subject were thus secured for each test on each of the three days.

The same subjects were used as in the first section of the experiment, except that one man and one woman were absent throughout. These subjects were, then, all trained and practically on their practise level in the tests, having perfected themselves by the 140 trials during the preceding four weeks' experiment. In this section the subjects were again divided into four squads. Squad I. took caffein along with soda fountain syrup and carbonated water, after the 6th trial on the 1st and 3d days, and a sugar of milk capsule at the same time on the 2d day. Squad II. served as a control squad. On the first two days they took only sugar of milk capsules, but on the last day, after the 6th trial, they took 3 gr. of caffein, which was followed by 2 gr. more about an hour and a half after the evening meal. Squad III. took 3 gr. of caffein on the 1st day, after the 6th trial. On the two remaining days they took only sugar capsules, the object being to trace the action of the original dose for at least three days after taking. Squad IV. took 6 gr. of caffein on the first day, and only sugar capsules on the days following, the object being here, as in Squad III., to trace the action of the first dose during the following two days.

C. The third section of the experiment was designed to determine the effect of caffein when taken along with food substance in the form of syrup such as is commonly contained in soda fountain drinks, and to compare this effect with the action of the syrup when taken with no caffein ingredient. This experiment occupied 7 days. On two of these days no dose was administered to the subjects. These are called blank days, and they show what sort of performance one may expect in the tests employed when thoroughly practised subjects are used and no drug of any kind taken. On two other days all the subjects took doses of plain syrup, served with carbonated water so as to enable the effects of simple sensory stimulation to become apparent. On the remaining three days the same syrup was served in the same way, except that 1.2 grains of caffein alkaloid were added to each glass of the drink. On one day 1 glass of the caffeinated syrup was given to all subjects 15 minutes before beginning the tests at the 3:10 period. On another day 3 glasses and on the third day 5 glasses were given, the three amounts thus containing 1.2, 3.6 and 6.0 grains of caffein.

The tests during this third section of the experiment were held five times a day, as in section 1, and at the same time of day. When the one glass dose was taken it was served just before the 3:10 test. In the other cases a dose was taken before each of the afternoon tests. As subjects in this section, twelve of the persons used in the tests of the previous month were used. They were hence practised in all the tests, thoroughly familiar with the method of procedure and perfectly adjusted to the experimental conditions. The whole group of 12 acted as a single squad, so that all received the same dose at the same time of day. The subjects in no case knew whether they were taking the plain or the caffeinated syrup. In fact they knew nothing about the character of the dose except that the experiment was to determine the effects of soda fountain syrups on mental and motor processes.

Subjects

In going through the tests at the appointed hour the subjects came to the various rooms in squads of three, the identity of the squads being permanent throughout a given section of the experiment. The tests were so distributed in the various rooms and among the various assistants that all the five squads would complete their tests in the respective rooms at approximately the same time. At a whistle signal on the part of the director the squads shifted from room to room, and so on through the five shifts which completed the hour's work. Each subject was given a number by which he or she was known throughout the experiment, and by which reference to individuals will be made in the chapters to follow. The following table gives the number and name of all the subjects, along with their age, sex, weight, occupation, previous caffein habits, and the squad to which each belonged in Section 1 and Section 2 of the experiment. The writer wishes at this point to acknowledge his obligation to these subjects for their faithfulness and zeal throughout the experiment.

Doses and Their Administration

Many sources of error exist, in such experiments, in the character of the dose and in the way in which it is administered. The principal dangers have been so clearly pointed out by Rivers that I can do no better than quote, at this point, the following important paragraphs from his chapter on the action of drugs.

"I can now pass to a feature of method . . . designed to eliminate the influence of certain psychical factors which have undoubtedly been allowed to affect the results of nearly all who have experimented on the action of drugs. Many

TABLE I

THE SUBJECTS

No.	Name	Age	Weight	M—Male F—Female	Occupation	Caffein Habits	Squad Sec. 1	Squad Sec. 2
1	C. R. A.	39	?	M	Teacher	Regular	I.	II.
2	E. A. B.	38	?	F	Wife of College Instructor	Regular	Worked alone at typewriting	
3	A. E. C.	39	159	F	Wife of Graduate Student	Abstainer	III.	IV.
4	H. W. E.	19	124	M	Student	Moderate	I.	I.
5	R. N. G.	33	105	F	Wife of Teacher	Regular	IV.	—
6	W. A. J.	33	125	F	Wife of College Instructor	Regular	IV.	III.
7	S. A. F.	19	153	M	Student	Moderate	I.	II.
8	C. L. L.	24	144	M	Graduate Student	Regular	II.	III.
9	A. M. McC.	21	130	M	Student	Abstainer	III.	III.
10	C. H. N.	28	157	M	Law Student	Occasional	IV.	IV.
11	F. C. R.	27	110	F	Wife of Graduate Student	Abstainer	IV.	I.
12	K. E. R.	24	160	M	Graduate Student	Regular	II.	III.
13	V. H. R.	22	175	M	Student	Regular	II.	—
14	B. E. S.	27	193	M	Graduate Student	Occasional	III.	IV.
15	S. R. S.	34	108	F	Wife of College Instructor	Occasional	I.	II.
16	T. W. V.	24	174	M	Law Student	Regular	IV.	III.

of these workers have considered the possibility that their results may have been influenced by suggestion, or of bias towards results which were to be expected theoretically, and some have shown that effects similar to those following the administration of a drug may be the consequence of the administration of a wholly inactive substance which is supposed by the subject to be the drug in question. Few, however, have adopted the obvious precautions which such considerations suggest (that of using a control substance).

"The factor which previous writers have considered under the title of 'suggestion' is far from being the only source of error in work on the action of drugs. Feré has shown that the sensory stimulation involved in the act of taking a drug into the mouth and swallowing it may have a very decided effect on the amount of work executed on the ergograph, but even this knowledge did not lead him to adopt any control in his numerous researches on drugs.

"There is however another factor which is probably more important than either sensory stimulation or suggestion, viz., the interest and excitement produced by taking a substance when the discovery of its effect is the motive of the whole experiment. . . . If such a condition of interest as that arising from its being the first or last day of an experiment, or that resulting from the view of the weight rising as the finger contracts, can have very appreciable effects on the amount of work, it is clear that so interesting an occurrence as the administration of a drug must have a decided influence and the interest so aroused will probably be equally great whether the nature of the drug is unknown, so that there is an element of mystery in the occurrence, or whether its nature is known.

"A difficulty which arises in drug experiments is due to the practise of taking as part of the normal diet substances which have an effect on the capacity for work; and this difficulty becomes especially great when it is one of these drugs which is the subject of the experiment.

"If the use of the active substance is only given up shortly before the commencement of the experiments, there is a further danger. Even in those who only take such a substance in moderate amounts, its disuse is probably followed in some degree by the craving which is so pronounced after discontinuance of large amounts, and, slight and hardly noticeable as this craving may be, it may yet be sufficient to produce an obvious effect when the article of which the person has been deprived is administered experimentally. The effect of the substance given experimentally may be the result, not of its normal physiological action, but of the satisfaction of the craving.

"In carrying out an experiment of this kind, extending over a number of days, it is essential that all the conditions of life be kept as constant as possible. The same amount of sleep must be taken every night, the meals must be of the same kind and at the same times every day, the same amount of exercise must be taken, and the same amount of other work done." (Rivers, "The Influence of Alcohol and Other Drugs on Fatigue," pp. 15–21.)

In the present experiment an attempt was made to take account of all the sources of error pointed out in this excellent analysis. The first error was avoided by administering, on days known only to the director, an inactive substance (sugar of milk) in the same manner and at the same time that the caffein doses were given on the remaining days. These days were not the same for all the subjects, and the result was that neither the subjects going through the tests nor the assistants who were making the measurements and records knew at any time whether the record was being made under the influence of caffein or of the inactive control substance.

In order to make the two substances completely indistinguishable and to reduce to a minimum the factor of sensory stimulation, the doses were administered in capsule form (except in a few test cases specified in the text). The caffein and the control substance presented the same appearance and neither substance was ever tasted. In some cases the capsule was taken along with a drink of water, but in most cases no such assistance was required.

The fact that the caffein days were thus unrecognizable helped to reduce the disturbing influence of excitement and interest. These factors were further reduced by running all subjects for one week on control doses only (quite without their knowledge, of course). This procedure not only served to get the subjects adapted to the conditions of the experiment before the drug doses began, but at the same time brought their performance to a more uniform practise level. Since all subjects gave up the use of all drugs three days before the experiments began, this additional week gave an interval

of 10 days in which those who had previously used caffein might become adapted to its discontinuance.

It has already been stated that all the subjects conformed to a fixed routine of time of meals, hour of retiring, amount of work, etc., so far as this was possible. And during the intensive experiment, in order to perfect this routine, all the subjects were fed at the same table and spent the whole day in the laboratory.

As a further check on the character and quality of the drug used, two commercial brands of caffein were administered and the records of administration of doses distinguished between these two brands. One of these (Schaeffer's) was identified and prepared in capsule form by the prescription department of Eimer and Amend, wholesale druggists in New York City. The other brand (Mallinckrodt's) was taken directly from the stock of the same firm. No difference was found in the action of the two brands, but the facts are given here simply as a point in the general technique of the experiment.

Supplementary Information

Through fixed routine of life on the part of the subjects, by the maintenance of uniform temperature in the laboratory, etc., it was endeavored to keep the conditions of the experiment as constant as possible. But no amount of precaution can perfectly control the conditions to which an organism is subject throughout a period of 40 days. In order to supplement these precautions, and for the personal information of the director and the convenience of the medical adviser, the results coming from the tests were further checked up by daily memoranda recorded by each subject throughout the experiment. Each individual kept a "daily health book," in which record was made of the condition of health and spirits in both forenoon and afternoon. Any unusual indications, symptoms, etc., were noted, the hour of appearance and the continuance of these indications, and their character in detail stated. This account was of course purely introspective. Any outside circumstances of an unusual or disturbing character were also reported. The approximate number of hours sleep was recorded after each night, and the quality of sleep classified as *better than usual, ordinary,* or *worse than usual.* In the case of the female subjects the beginning and end of the menstrual period were also noted. The hearts of these subjects were also examined stethoscopically at the beginning of the experiment by the medical assistant.

At the close of the complete experiment each subject was requested to reply to the following questionnaire:

QUESTIONNAIRE

(To be answered by all subjects in the book provided)

1. If before the experiment began you were accustomed to the use of coffee, tea, tobacco or any form of alcohol, have you found yourself missing or longing for any of these during the past five weeks, or have you been able to go without them without any desire or discomfort? Specify concerning each of the substances mentioned. Explain as fully as possible with reference to coffee and tea in particular.

2. On the whole do you find yourself in better or worse general condition of health, spirits and general efficiency, or do you notice any change at all? What was your weight when the experiment began? What is it now?

3. Have you at any time during the experiment read up in any kind of treatise a discussion of the supposed effects of caffein on mental and physiological processes, or in any other way made such inquiry? If so, do you think that knowledge or suggestion thus acquired has in any way influenced your health reports, or suggested special symptoms which you might otherwise have ignored? Kindly discuss this as fully as possible.

4. Will you kindly discuss each of the following tests to the best of your ability, giving as much information as possible, from your own observation and self-examination, on the questions which follow the list of tests. All that you can say here with certainty, and with no attempt at mere guessing will be much appreciated.

Color-naming Test,	Weight Test,
Naming Opposites,	Discrimination Reaction,
Calculation Test,	Tapping Test,
Cancellation Test,	Steadiness Test.
Three-hole Test,	

(*a*) What particular difficulties did you have with the test in the beginning? Did you overcome these difficulties in any conscious way which you can here describe or did you just happen upon the better method quite unexpectedly and unconsciously?

(*b*) On days when you did not seem to be able to do the test as well as usual, what seemed to be the difficulty? Were you able to overcome this difficulty in any way on the days in question or did it simply stay and go away later of its own accord?

(*c*) If in the course of the experiment you came to change your method of doing the test from time to time will you kindly describe these changes, tell in what they consisted, what suggested them, and whether they proved better or worse than the original methods. Did your chief improvement come from simple practise and repetition, from observing the better methods employed by others, by deliberately trying improvements of your own, or by accidentally happening upon better methods? Explain in each case as fully and clearly as you can.

Kindly answer the above questions as fully as you can, for each of the tests.

5. Have you at any time during the experiment been able to know whether you were taking caffein or not, in your capsules, at the time of taking? This does not mean, of course, after any effect which the substance may have had begun to show itself. If so, kindly state how and when.

6. Will you kindly state at this point whether or not you have conformed to all the requirements concerning sleep, diet and regular habits which you agreed to observe throughout the experiment.

The Tests

The tests employed have been briefly enumerated in the preceding questionnaire. Each will be described in detail in the appropriate chapters of the following discussion of results. Except in the case of the size-weight illusion and in that of the steadiness test, the quality and quantity of the performance remained constant and the measurement was made in terms of the time of performance (speed). A rough record was made at the time of the test and this record was subsequently copied into a final book and a duplicate of this book made. The individual records were then averaged in various ways, and these averages placed in separate books. The averages of the various squads were also computed and recorded separately. These five methods of recording were adhered to in all the tests, by all the assistants. No assistant was aware of the records made at any time by any of the subjects in any test save those of which he was in charge. Except for a weekly announcement of the best five records in each test, the subjects themselves knew nothing concerning the record they were making except in so far as this knowledge was based on their own opinion of their performance.

Assistants

The writer's appreciation of the splendid service rendered by the following corps of assistants is here gladly expressed.

Laboratory Assistants

Leta Stetter Hollingworth, A.B., Assistant Director.
Miss L. G. Stevenson, A.B., M.D., Assistant and Medical Adviser.
Miss Margaret Tower Hart, A.B., Assistant in Experimental Psychology, Barnard College.
A. E. Chrislip, A.B., M.A., Candidate for Ph.D. in Psychology, Columbia University.
A. J. Culler, A.B., Candidate for Ph.D. in Psychology, Columbia University.
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CHAPTER III

Description of the Tests

I. Perception and Association

Since thinking is so largely a matter of the association of ideas, a set of three simple association tests, representing different degrees of complexity, were chosen to represent this sort of mental process in the present experiment. These three degrees of complexity are fairly clearly recognized in daily life as well as in the classical laboratory experiments. (1) The names of the objects of our experience are associated with the direct perception, through some avenue of sensation, of the objects themselves. (2) Ideas are associated with other ideas, names with other names, words with other words. (3) Tasks and situations of a more or less specific character are associated with ideas which will handle or solve them effectively.

1. *Association of Ideas and Words with Simple Objects of Experience.*

This process is illustrated by the *Color-naming Test.* The experiment is designed to measure the speed with which the name or idea can be brought to consciousness upon the sight of the object, which is in this case a color. On a white cardboard background, 26 cm. square, were pasted 100 colored squares (1 cm. sq.) of paper. Each of the colors, red, orange, yellow, brown, green, blue, violet, pink, gray and black, occurred 10 times on the card, the 100 squares being arranged in a chance order, and placed 1 cm. apart. The card was placed face downward on the table before which the subject sat. The instructions were to turn the card over at a given signal from the assistant ("Ready," and, after 2 seconds, "Go"), and to read the 10 lines of colored squares through, naming aloud, as quickly as possible, the correct name for each square. The lines were read from left to right. The assistant held a similar card and said "No" whenever a color was incorrectly named, and the reader was required to give the correct name before proceeding. The score in this test was represented by the total time (recorded by the assistant in fifths of a second) required to name through the 100 colors correctly.

In order to eliminate differences and variations due to possible unfamiliarity with color names, each subject was given a few preliminary trials in which the proper simple name was associated with

each of the colors. In order to eliminate any memory effect which might have come from naming the series over repeatedly in the same order, the plan was followed of turning the card about (90 degrees) on the second trial of the day. This was done for each of the five trials on a given day, the last order thus being the same as the first, for any given day, the three other orders having meanwhile intervened. This practise was followed only during the first four weeks, in which only five tests were made daily. The same sequence of orders, *A, B, C, D, A,* was followed on all the days. During the intensive experiment (three days, 15 trials daily) no changes in order were made, order *A* being used throughout. As a matter of fact very little memory effect was found to be present. At the close of the experiment all the subjects were tested for memory effect by first asking them to recite the various orders from memory, and then by giving them the first three names of a given order and asking for the following colors. In spite of the fact that the colors had been named 220 times by each subject during the experiment, no one was able to do more than give a few groups of three or four colors in their proper order, and even the proper location of these groups in the series or on the card was impossible. The assistant who had gone over the test about 3,300 times knew scarcely more about the order of the colors than did the subjects themselves. There had been of course no intention to memorize, in the test, and the result affords an interesting suggestion with respect to the part played, in memory processes, by the "determination to learn."

In the beginning of the experiment this test constitutes a measure of the individual's familiarity with colors and color names, and his accuracy of color discrimination, as well as the absolute quickness of the association process involved and the facility of articulation. As the experiment progresses it affords a measure of the individual's ability to improve by practise, his degree of interference as shown by the tendency of a preceding idea to inhibit or interfere with the correct perception and expression of the next stimulus. It also measures the regularity of his performance and his susceptibility to fatigue. The Color-naming Test has been recommended by Cattell and Farrand ("Physical and Mental Measurements of the Students of Columbia University," *Psychological Review,* November, 1896, p. 642) and has been used for several years in the Columbia Laboratory (see Wissler, "The Correlation of Mental and Physical Tests," *Psychological Review,* Monograph Supplements, Vol. III., No. 6, 1901).

2. *Association of One Idea with Another Specific Idea.*

This process is represented in our experiment by the test of *Naming Opposites.* On a cardboard which lay face downward before the subject was the following list of 50 adjectives, typewritten, in two parallel vertical columns of 25 each. The instructions were to turn the card over at the given signal and proceed down the list, naming aloud the *opposite* (in meaning) to each word in the order in which it occurred. The time required for this performance was measured by the assistant in fifths of a second. In order to make the test one of association time rather than of linguistic knowledge, such errors as giving an adverb as the opposite of an adjective, etc., were pointed out. If an unacceptable word was given the assistant exclaimed "No" and the subject was required to give a correct opposite before proceeding. The same fifty words were used at each trial, but each time they occurred in a new and chance order, determined by shuffling a deck of cards on each of which one of the words was written, and making out the typewritten list in the order in which the cards turned up.

NAME THE OPPOSITE OF EACH WORD, IN TURN, AS QUICKLY AS POSSIBLE

loud	fertile	vague	rash	tragic
slovenly	wise	ancient	ripe	graceful
innocent	masculine	foreign	dangerous	shallow
broad	beautiful	timid	prompt	drunk
public	sacred	harmonious	fickle	cloudy
stale	brief	coarse	aristocratic	sharp
sickly	defective	noisy	peculiar	stormy
gay	helpless	past	talkative	idle
soothing	expensive	hostile	attractive	savage
cowardly	doubtful	gentle	victorious	lazy

These words were chosen from a list of 200 which had been previously applied by Professor R. S. Woodworth to many individuals, measuring the time required to name the opposite of each word when the words were presented separately instead of serially. The above list of 50 adjectives were chosen because they all fell into the class of "moderately difficult," their average times ranging from 2 to 5 seconds.

The *Opposites Test* is a much used one in experimental and educational psychology and has been found to correlate to a fairly high degree with other tests designed to measure "mental ability."[1] As the test is conducted the mental process is essentially one of con-

[1] See, for example, F. D. Bonser, "Reasoning Ability of Children," Columbia Contributions to Education, No. 37.

trolled association, with the quality and quantity of the performance constant and the time variable. To think of the exact answer to a question, the precise address of a friend, the exact shade of meaning of a word, delicate distinctions of connotation in the use of language, all involve processes of controlled association, processes in which, from many ideas which the stimulus calls up, the one appropriate idea is recognized, selected and expressed, while the false or inadequate ideas are repressed. Hence this test indicates the ability of the individual to select the appropriate response from the host of ideas which follow in the wake of a stimulus word. It is an index of speed, accuracy, linguistic feeling, and of the ability to repress useless or irrelevant ideas. At the same time it shows the ability of the individual to improve by practise in such a performance, as well as the regularity of that performance. It is a test of association processes, but of association processes of a considerably more complex kind than those involved in the *Color-naming Test.*

3. *Association of an Idea with a Specific Task or Situation.*

A still more complex stage of association is found when a specific task or situation calls for an appropriate and immediate response. The ideas themselves are not given. The individual must provide his own ideas and images, and may manipulate them in his own way, but he must in some way come out of the process with the right response. It is thus a case of evolving an idea to meet an unexpected situation. The question will be, how quickly can the individual manipulate his mental processes so as to call up the right idea in his consciousness and set up movements of articulation which will express to an onlooker the result of his thinking. The *Calculation Test* was chosen to represent this type of association. A card was prepared containing 50 two-place numbers between 20 and 80, all numbers ending in 0 being omitted.[2] These 50 numbers occurred in a random order, and each number occurred but once in a list. The subject was required to turn the card face upward at the starting signal, and, without the aid of any graphic device, to add 17 mentally to each of the numbers on the card. The answer was to be spoken aloud and was checked up by the assistant who held the key card containing the correct answers. In case of a false calculation the subject was required to correct his answer before proceeding. The time required to perform the 50 additions was measured in fifths of a second. At the next trial the same numbers appeared on the card,

[2] For demonstration of the advantages of this type of calculation test see F. L. Wells, "Standard Tests of Arithmetical Associations," *Journal of Philosophy, Psychology and Scientific Methods*, Vol. IV., No. 19, September 12, 1907, pp. 510–512.

but in a new random order. In the intensive experiment the list was increased to 75 numbers, 25 of the original ones thus appearing twice in the series. During the experiment of the last week, 100 numbers were used, each of the original 50 thus appearing twice in random order.

II. *Discrimination, Attention and Judgment*

In order to determine the influence of caffein on such higher mental process as sensory discrimination, attention and judgment, three tests were employed, the familiar size-weight illusion, a cancellation test, and a series of measurements of choice-reaction times to color stimuli.

(*a*) *Discrimination.*

In order to determine whether or not such release of central control as might conceivably be produced by caffein would result in a correspondingly increased susceptibility to illusion, what is technically known as the size-weight test was employed.[8] From a group of 14 cylindrical weights of the same size (2.5–3.5 cm.) but differing in weight (from 15 to 80 grams, by increments of 5 grams) the subject was required to select the one which seemed to him equal in weight to a constant standard block which was several times the size of the weights constituting the series. This standard was a 55 gram weight, cylindrical in form, 4 cm. in height and 7 cm. in diameter. The weights rested on a flat cushion made of heavy towelling, and were lifted with thumb and forefinger, the weights being always compared with the standard and never with each other. The normal tendency here is to select a weight which is much lighter than the standard block, usually less than half as heavy. The subjects were all unaware of the presence or character of the illusion and were unable to identify the weight selected on previous occasions.

The normal illusion was present with all subjects, and increased in amount as the experiment progressed. But comparison of the caffein days with the control days shows no difference in the amount of the illusion. It is possible that this was due to the fact of the 5 gram differences between the weights. No difference smaller than 5 grams could thus be detected, although some influence might have been disclosed had the weights been graded by smaller amounts of difference. Since this test failed to yield any result it was discontinued after the first four weeks and was not used during the intensive experiment nor during the final experiment of one week. Since the results of this test have no apparent bearing on the character of the caffein influence they are not included in this monograph.

[8] See E. W. Scripture, "The New Psychology," pp. 272–282.

(*b*) *Attention and Discrimination Combined.*

The Cancellation Test.—Various forms of the cancellation test have been employed in investigations designed to measure the degree of attention, distraction, discrimination, fatigue, etc. In the various forms in which the test has been used the task has been that of crossing out all the cases of a given letter, figure, word, or symbol, or some combination of these occurring on a printed sheet along with other material from which the given symbols have to be discriminated. In these tests the measure usually consists of the time required to complete a given amount of cancellation correctly. It is assumed that the best speed will be made under conditions of maximal attention and that any tendency to distraction will be reflected in the speed of performance provided the quantity and quality of the work remain constant.[4]

Such a cancellation test was used in section 1 of the present experiment. A printed sheet contained each of the digits from 0 to 9, repeated 100 times. The sheet contained 20 lines, and each digit occurred 5 times in each line. Aside from this regularity the distribution represented a chance order. The subject was required to begin at the upper left hand corner and to cross out with a pencil all of the 2's, 3's, 5's, 6's, or 8's. A different digit was used at each of the five daily trials, the order being that in which the digits are named above. Obviously these five digits can not be distinguished with equal ease and speed from the background of the printed sheet, so that the absolute speeds made at different times during the day can not be compared except in terms of ratio. But, contrasting caffein days with control days, either the totals or the separate trials at the various hours may be compared independently of the digit used at the time. In order that the quantity and quality of the performance be kept constant throughout, the subjects were informed that each digit would occur five times in each line, and were instructed to mark off all five in a given line before proceeding to the next one.

This test is a difficult one to handle in practise because the individual subjects will differ in their acuity of vision and in their susceptibility to the eyestrain which the test easily induces. To use the total number of lines (20) on the sheet was found to be impracticable. During the preliminary week only ten lines were used, and after that the number was increased to fifteen lines, at which it remained throughout the remaining three weeks in which caffein was administered. One of the subjects (No. 1) of the control squad was unable to continue the test after the first few days because the eye strain involved rendered its performance painful.

[4] See G. M. Whipple, "Manual of Mental and Physical Tests," pp. 254–270.

(*c*) *Discrimination and Choice Reaction.*

This test was made with the aid of the "Columbia" chronoscope, a form of the pendulum chronoscope designed by Professor Forbes, of the department of physics, Columbia University. A spring release key which presented a colored disc in the exposure aperture, set free at the same instant a pendulum which swung across a scale graded in *sigma* until the pressing of a key on the part of the subject completed an electric circuit through a pair of magnets. These magnets caught the pendulum in its swing and held it before the graded scale until the record could be read by the operator. The subject was instructed to react to the appearance of a red disc by pressing, as quickly as possible, with the forefinger of the left hand, a telegraph key in circuit with an electric buzzer. On the appearance of a blue disc he was to react in a similar way on a key in his right hand. This key was in circuit with the chronoscope. Preliminary trials practised him in this process. At the same time occasion was taken to warn him against making false responses, which thereafter, with most subjects, occurred only infrequently. Record was, however, made of all such false reactions. Ten correct reactions to the blue disc were secured at each sitting, and interspersed with these (in a chance order determined by the appearance of reds or blacks in a shuffled deck of cards) from five to ten reactions to the red disc. The number of reds was varied in this way in order to prevent anticipatory reactions. The ten reactions for each sitting were averaged and their mean variation from the average computed. These two figures constituted the record for the given trial. The standard precautions concerning ready signal and interval were observed, and the mechanism concealed from the subject.[5]

III. *Motor Tests. Steadiness, Speed and Coordination*

1. *The Steadiness Test.*—The steadiness with which the individual could hold the outstretched arm was measured in the following manner: A metal rod 2.5 mm. in diameter was held in a hole formed in a brass plate. During the first four weeks the diameter of this hole was 6 mm. and during the rest of the experiment 4.5 mm. Every contact of the rod with the sides of the hole was registered by an automatic electric counter. The task was to stand unsupported by the table on which the apparatus was placed and to hold the rod in the hole for one minute with as few contacts as possible. The test

[5] For significance and technique of the discrimination reaction experiment see J. McKeen Cattell, *Philosophischen Studien*, 1886, III., p. 460; Ladd and Woodworth, "Physiological Psychology," pp. 470–499.

thus shows the general stability of the nervous system and the precision with which one set of muscles can be delicately balanced against another. Since all movements beyond the slightest tremor are recorded by the apparatus (especially when the smaller hole is used) any increase in trembling, twitching or general nervousness is easily detected so far, at least, as the horizontal plane is concerned. (For discussion, of the technique and significance of the steadiness test see Ch. V; also cf. Whipple, "Manual of Physical and Mental Tests," pp. 123–127.)

2. *The Tapping Test.*—Using the above described metal rod held in the right hand, the subject executed as rapidly as possible 400 taps on a solidly planted metal base. Each tap was recorded by the electric counter and the time required for the first 200 and the last 200 taps was measured in fifths of a second with a stop watch. This is the simple form of the tapping test used by Bryan and others, and is much too crude for an intensive study of the course of fatigue or the regularity of the performance. But more elaborate methods were impracticable in the present experiment, and the investigation in this test was limited to the influence of caffein on the total time required to make the given number of taps. In section 3 the number of taps to be made was raised to 500. (For full discussion of the technique and significance of the tapping test see F. L. Wells, *American Journal of Psychology,* Vol. XIX., pp. 345–358 and pp. 437–483; Vol. XX., pp. 38–59 and pp. 353–363. Also Whipple, "Manual of Mental and Physical Tests," pp. 100–115.)

3. *Coordination. The Three Hole Test of Combined Accuracy and Speed.*—The three hole test, as it is technically called, includes, along with the factors of steadiness and speed, which are essentially motor or physiological, the more strictly mental factor of coordination. An oak plate tilted at an angle of 45 degrees to the base board, contained three brass-line holes arranged in the form of an equilateral triangle, about 8 cm. apart. Contact of the metal rod with the bottom of a hole made an electrical connection which was recorded by the automatic counter. The subject held the rod in his left hand because the right hand had just been used for the tapping test. The task was to insert the rod into each of the three holes successively as rapidly as possible until 100 insertions had been made. The time required for this process was measured by the assistant with the stop watch in fifths of a second. Success in this test requires not only that a single set of muscles be brought into harmonious action, as in the tapping test, but also that several sets be coordinated with each other, under the guidance of a visual impression. In making the movements most of the muscles of the arm are in-

volved, as are the external muscles of the eye and its mechanism of accommodation. Arm movements must be coordinated with eye movements as accurately and at the same time as quickly as possible. The test is thus a measure of combined accuracy and speed—it measures the efficiency with which such stability and activity as are available can be brought under the control of a purely mental effort—the coordination of a complex set of activities focused on the accomplishment of a single and definite task. The series of motor tests, of which this is the third, seem to afford significant indices of general motor capacity, and usually reveal clear cut individual and sex differences in inertia, speed, accuracy, fatigue and rate of improvement.

CHAPTER IV

The Influence of Caffein on the Tapping Test

The tapping test seems to have been little used in experiments on the influence of drugs. The motor tests usually employed have been chiefly ergographic or dynamometric in character and designed to measure the force and number of contractions of which a muscle or set of muscles is capable when working against a load. The tapping test measures rather the speed with which unloaded muscles can execute successive contractions of a narrow range.

The following individual curves show in a preliminary way the stimulating effect of caffein on this performance. The curves show in each case the time required to execute 400 taps. The broken line record was made on control days and the solid line record on caffein days, the two kinds of days alternating regularly. The first pair of each set show forenoon records made before any dose whatever was taken, hence are both control or normal records. In all three cases there is no difference between these two curves. Both show practise throughout the course of the experiment, but caffein days show no superiority over control days. The second pair of curves in each set shows the records made in the afternoon, some time after the capsule had been taken. The superiority of the caffein days is here apparent. Stimulation is present for all amounts.

In the following curves the first pair for each subject gives records before the dose and the second pair the records after the dose. The solid line represents caffein days and the broken line control days. Unit, the time required for 400 taps.

These three individual records are typical of the behavior of the other members of the caffein groups. Considerable individual differences are shown, varying from no very marked effect at all (as with Subject VI.) to the great stimulation shown by Subject XIV. But in no case is there any evidence of continued retardation after caffein. The general tendency can then be more safely discussed on the basis of the squad averages, which will show under each condition the mean effect on the several individuals comprising the squads.

In giving these averages the mean variations would be of no value since there are but 3–5 individuals in each squad and the mean variation of their average record at a given test would simply reflect their individual differences. Since the abilities of the various indi-

viduals, though constant in themselves, are considerably different from each other, the M.V.'s of the averages will always be much larger than the difference produced by the use of caffein on any one person's record. Hence it seems most informative and economical of

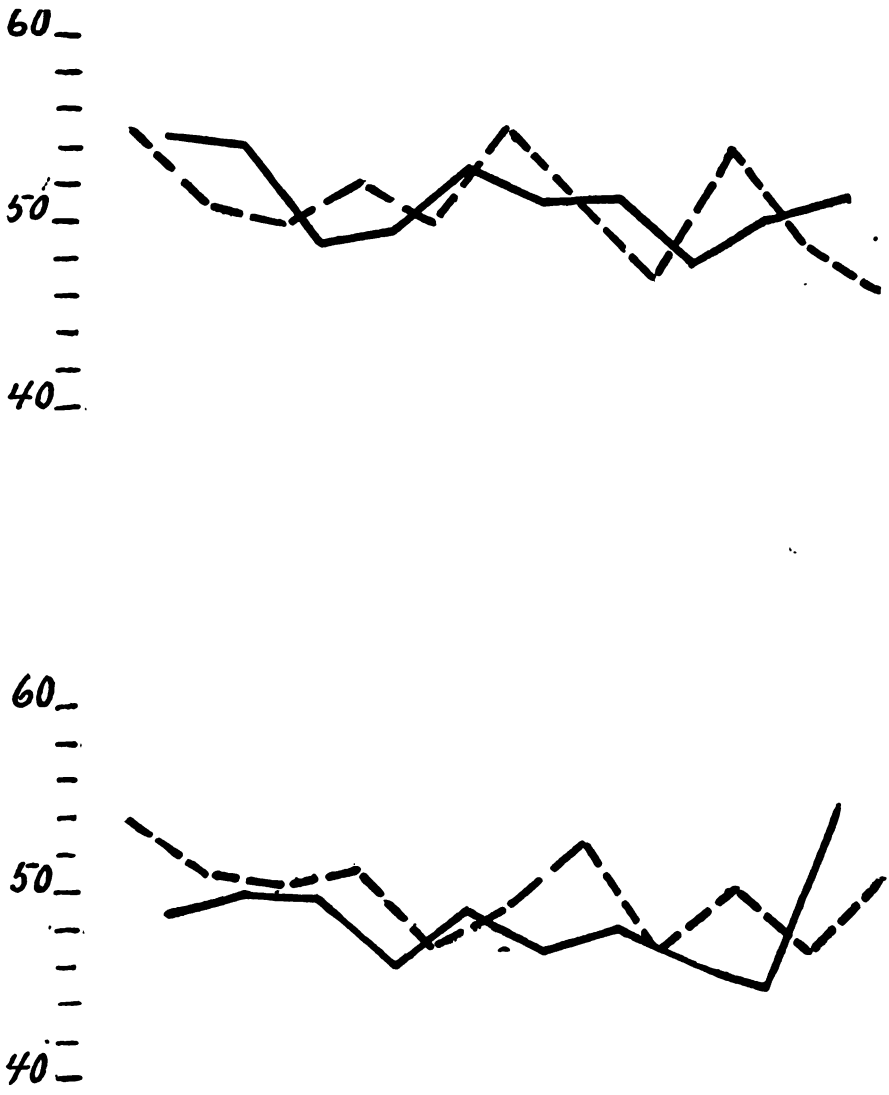


FIG. 1. Subject VI., 12:00 and 3:10.

space to treat the total time required by the squad at any given test, rather than the time required by each individual, as a unit of performance. There is then no question of M.V., since the total squad

time (divided by the number of persons in the squad in order to reduce the magnitude of the numbers) constitutes a single measurement. This method of treating the squad as an individual thus tends to minimize the effect of variations due to foreign factors and to compensate for the personal variations of the individual subjects.[1]

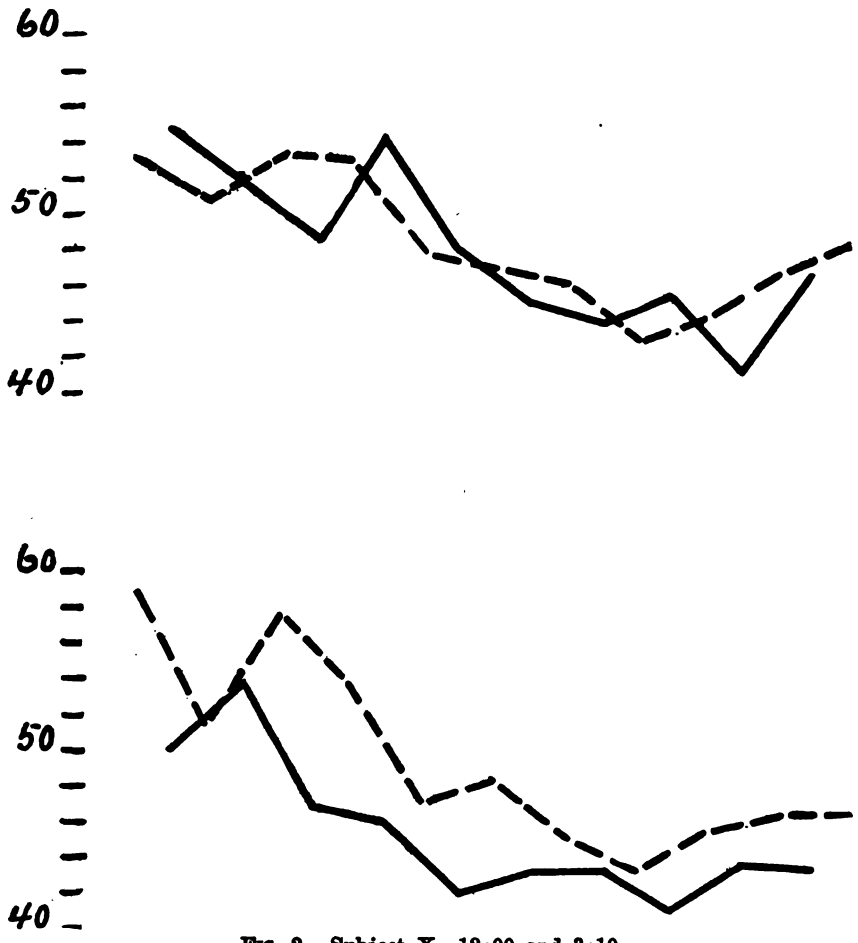


FIG. 2. Subject X., 12:00 and 3:10.

In the tables that follow are given the squad averages for each hour of the day on all the days of Experiment *A*, except that the first week of practise, in which no caffein was administered, is not included. The hour of the dose is also indicated in each table, *s* signifying sugar and a number of grains (as 3 gr.) signifying a

[1] This plan is adhered to in reporting the other tests as well.

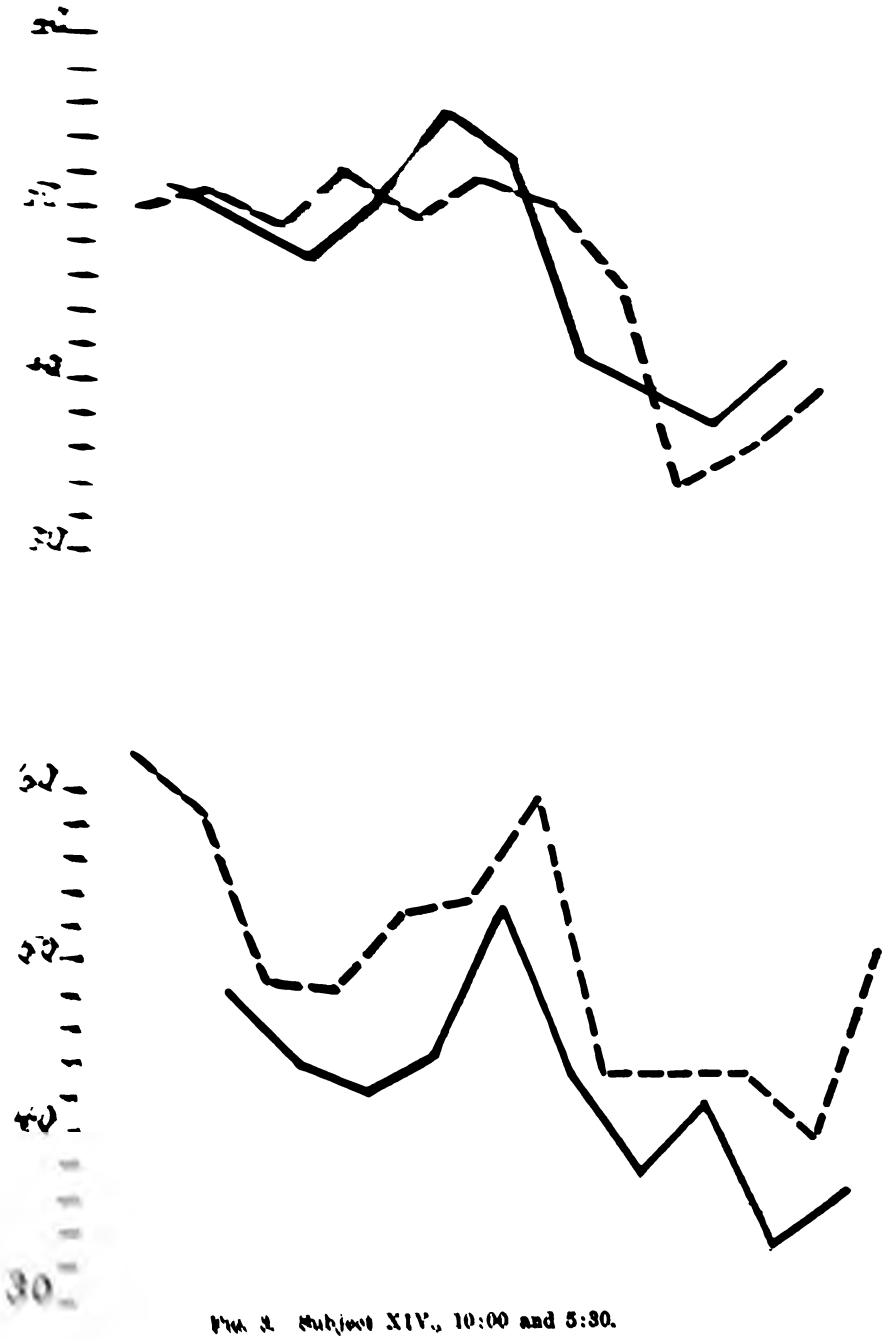


FIG. 1. Subject XIV., 10:00 and 5:30.

dose of caffein. The records for caffein days are in italics, but it should always be borne in mind that it is only after the hour of the dose that the italics indicate performance under the influence of caffein. If the caffein influence holds over until the following day the effect must be looked for in the characteristics of the unitalicized records of the day in question.

In Experiment *A*, Squad I., is the control squad who took only sugar doses for 25 successive days, the last 18 of which are shown in Table II. But in treating the data from this squad the records are handled just as though the caffein days for Squads III. and IV. had also been caffein days for Squad I. Comparison of these pseudo-caffein days with the remaining days, in Squad I. might be expected to indicate the likelihood that any result found in the case of the other squads is only a chance result.[2]

TABLE II

TAPPING. SQUAD I. (CONTROL), EXPERIMENT *A*

Control doses only. Records treated as though odd days were caffein days and only even days control

	February													
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23
7:45	58.5	*55.9*	58.0	*56.4*	55.8	*53.9*	54.7	*54.5*	53.5	*54.8*	55.9	*52.5*	55.6	*52.4*
10:00	56.6	*57.6*	57.9	*55.1*	55.8	*54.8*	56.4	*52.1*	53.7	*54.0*	52.6	*54.3*	51.3	*52.2*
12:00	58.7	*57.9*	58.0	*55.7*	55.2	*56.9*	54.3	*55.1*	52.6	*55.5*	51.7	*51.8*	53.4	*51.5*
1:00	Dose, sugar capsules only, daily.													
3:10	59.7	*56.1*	56.2	*55.3*	52.7	*55.0*	56.3	*54.1*	53.6	*53.1*	54.1	*51.8*	57.7	*50.9*
5:30	64.9	*57.3*	57.2	*55.8*	56.7	*56.4*	53.8	*52.3*	54.1	*51.4*	51.3	*51.0*	51.2	*52.1*

Turning now to the examination of Tables II.–V., reading along the horizontal lines, gives the record for any given hour of the day, on each day of the experiment. The italicized caffein-day records can thus easily be compared with the control records for the same hour on both the preceding and the following days. Reading down the vertical columns gives the successive records made on any single day. Comparisons of records made before and after the dose are thus easy to make.

With the data presented in this form only it is not easy to discuss

[2] The writer regrets the impossibility of presenting in the form of curves all of the vast amount of data treated in this monograph. It would greatly facilitate comparison on the part of the reader, but is quite out of the question because of the amount of space that would be required. Even the inclusion of the curves would not do away with the desirability of presenting the actual figures in tabular form. These figures will always be given in such shape that any set of results which the reader wishes to examine more minutely may easily be platted from the data given in the tables.

TABLE III

TAPPING. SQUAD II., EXPERIMENT *A*

Caffein three successive days, alternating with three control days

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	49.5	49.2	*48.5*	*48.3*	*47.9*	43.7	45.1	*46.4*	*43.7*	*46.1*	46.3	49.8	43.3	*41.8*	*42.1*	*42.1*	42.5	40.7	40.9	*42.8*	42.2
10:00	48.5	48.1	*51.7*	*49.0*	*46.1*	46.6	45.2	*43.9*	*43.9*	*44.9*	43.5	46.6	45.8	*42.7*	*44.7*	*43.0*	41.5	40.7	40.4	*41.6*	45.9
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*4 gr.*	*4 gr.*	*4 gr.*	S	S	S	*6 gr.*	S
12:00	49.0	48.0	*47.4*	*47.3*	*46.8*	45.9	47.2	*42.8*	*43.7*	*46.7*	44.5	43.9	46.9	*38.9*	*46.3*	*44.2*	41.3	40.0	39.1	*40.7*	45.3
3:10	52.3	48.8	*46.8*	*45.2*	*47.9*	46.1	44.2	*44.7*	*43.0*	*44.5*	45.3	46.1	44.2	*43.5*	*44.2*	*41.6*	42.3	40.9	40.9	*38.3*	43.2
5:30	46.3	48.4	*48.2*	*46.0*	*46.7*	44.3	43.5	*43.0*	*43.0*	*45.3*	39.9	43.0	41.2	*40.5*	*41.1*	*42.1*	43.0	42.1	41.0	*40.9*	46.4

TABLE IV

TAPPING. SQUAD III., EXPERIMENT *A*

Caffein on alternate days, with lunch

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	58.0	*57.0*	56.9	*52.9*	59.5	*58.0*	53.2	*54.1*	54.7	*56.6*	55.3	*56.5*	48.3	*54.1*	54.1	*47.9*	49.3	*48.6*	48.7	*54.2*	55.7
10:00	56.9	*58.9*	53.8	*55.3*	55.2	*54.1*	54.1	*53.4*	55.2	*56.6*	55.1	*54.5*	49.7	*46.0*	48.3	*45.2*	43.2	*43.3*	44.0	*45.3*	44.4
12:00	57.9	*67.1*	54.7	*55.0*	57.6	*57.7*	54.5	*51.9*	56.4	*56.7*	52.9	*45.8*	50.9	*47.9*	45.3	*46.9*	50.7	*42.5*	45.3	*48.3*	50.3
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	60.0	*58.7*	54.9	*55.6*	53.4	*51.3*	51.9	*50.1*	53.8	*50.6*	48.1	*51.8*	49.3	*45.8*	44.9	*43.9*	46.7	*43.1*	50.3	*44.5*	50.9
5:30	60.5	*48.7*	52.9	*53.7*	52.9	*51.2*	52.7	*50.9*	53.7	*53.0*	52.9	*45.9*	48.3	*42.5*	47.4	*45.9*	53.3	*41.5*	46.2	*42.9*	49.5

TABLE V

TAPPING. SQUAD IV., EXPERIMENT *A*

Caffein on alternate days, about 2 hours after lunch

	February																	March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	56.6	*55.4*	55.0	*54.9*	56.0	*53.1*	53.5	*51.6*	51.7	*53.8*	56.6	*50.9*	49.5	*53.9*	52.0	*50.6*	52.0	*53.1*	51.8	*51.0*	50.9
10:00	57.8	*51.8*	54.8	*54.8*	53.7	*55.8*	53.1	*54.9*	51.9	*52.3*	51.4	*51.4*	49.4	*51.4*	51.4	*51.2*	48.2	*52.4*	53.2	*50.8*	53.7
12:00	56.8	*56.9*	55.7	*55.0*	54.6	*52.3*	53.9	*54.2*	53.1	*53.1*	53.4	*52.8*	51.5	*51.9*	53.8	*51.4*	52.2	*52.1*	51.8	*51.3*	53.5
1:45	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	60.2	*53.4*	54.5	*54.7*	55.1	*53.8*	53.2	*49.9*	52.9	*51.0*	52.4	*50.6*	51.3	*50.0*	49.4	*48.1*	52.4	*49.3*	50.0	*51.7*	51.8
5:30	55.6	*55.1*	55.8	*55.5*	54.3	*53.8*	53.0	*49.9*	53.7	*49.5*	50.2	*51.1*	51.0	*51.8*	50.7	*48.0*	51.4	*47.9*	52.5	*49.0*	51.0

TABLE III

TAPPING. SQUAD II., EXPERIMENT *A*

Caffein three successive days, alternating with three control days

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	49.5	49.2	*48.5*	*48.3*	*47.9*	43.7	45.1	*46.4*	*43.7*	*46.1*	46.3	49.8	43.3	*41.8*	*42.1*	*42.1*	42.5	40.7	40.9	*42.8*	42.2
10:00	48.5	48.1	*51.7*	*49.0*	*46.1*	46.6	45.2	*43.9*	*43.9*	*44.9*	43.5	46.6	45.8	*42.7*	*44.7*	*43.0*	41.5	40.7	40.4	*41.6*	45.9
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*4 gr.*	*4 gr.*	*4 gr.*	S	S	S	*6 gr.*	S
12:00	49.0	48.0	*47.4*	*47.3*	*46.8*	45.9	47.2	*42.8*	*43.7*	*46.7*	44.5	43.9	46.9	*38.9*	*46.3*	*44.2*	41.3	40.0	39.1	*40.7*	45.3
3:10	52.3	48.8	*46.8*	*45.2*	*47.9*	46.1	44.2	*44.7*	*43.0*	*44.5*	45.3	46.1	44.2	*43.5*	*44.2*	*41.6*	42.3	40.9	40.9	*38.3*	43.2
5:30	46.3	48.4	*48.2*	*46.0*	*46.7*	44.3	43.5	*43.0*	*43.0*	*45.3*	39.9	43.0	41.2	*40.5*	*41.1*	*42.1*	43.0	42.1	41.0	*40.9*	46.4

TABLE IV

TAPPING. SQUAD III., EXPERIMENT *A*

Caffein on alternate days, with lunch

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	58.0	*57.0*	56.9	*52.9*	59.5	*58.0*	53.2	*54.1*	54.7	*56.6*	55.3	*56.5*	48.3	*54.1*	54.1	*47.9*	49.3	*48.6*	48.7	*54.2*	55.7
10:00	56.9	*58.9*	53.8	*55.3*	55.2	*54.1*	54.1	*53.4*	55.2	*56.6*	55.1	*54.5*	49.7	*46.0*	48.3	*45.2*	43.2	*43.3*	44.0	*45.3*	44.4
12:00	57.9	*67.1*	54.7	*55.0*	57.6	*57.7*	54.5	*51.9*	56.4	*56.7*	52.9	*45.8*	50.9	*47.9*	45.3	*46.9*	50.7	*42.5*	45.3	*48.3*	50.3
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	60.0	*58.7*	54.9	*55.6*	53.4	*51.3*	51.9	*50.1*	53.8	*50.6*	48.1	*51.8*	49.3	*45.8*	44.9	*43.9*	46.7	*43.1*	50.3	*44.5*	50.9
5:30	60.5	*48.7*	52.9	*53.7*	52.9	*51.2*	52.7	*50.9*	53.7	*53.0*	52.9	*45.9*	48.3	*42.5*	47.4	*45.9*	53.3	*41.5*	46.2	*42.9*	49.5

TABLE V

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	61.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12:00	66.8	60.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1:45	8	1 gr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:10	60.2	58.4	[illegible]	54.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5:20	56.6	55.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE III

TAPPING. SQUAD II., EXPERIMENT *A*

Caffein three successive days, alternating with three control days

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	49.5	49.2	*48.5*	*48.3*	*47.9*	43.7	45.1	*46.4*	*43.7*	*46.1*	46.3	49.8	43.3	*41.8*	*42.1*	*42.1*	42.5	40.7	40.9	*42.8*	42.2
10:00	48.5	48.1	*51.7*	*49.0*	*46.1*	46.6	45.2	*43.9*	*43.9*	*44.9*	43.5	46.6	45.8	*42.7*	*44.7*	*43.0*	41.5	40.7	40.4	*41.6*	45.9
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*4 gr.*	*4 gr.*	*4 gr.*	S	S	S	*6 gr.*	S
12:00	49.0	48.0	*47.4*	*47.3*	*46.8*	45.9	47.2	*42.8*	*43.7*	*46.7*	44.5	43.9	46.9	*38.9*	*46.3*	*44.2*	41.3	40.0	39.1	*40.7*	45.3
3:10	52.3	48.8	*46.8*	*45.2*	*47.9*	46.1	44.2	*44.7*	*43.0*	*44.5*	45.3	46.1	44.2	*43.5*	*44.2*	*41.6*	42.3	40.9	40.9	*38.3*	43.2
5:30	46.3	48.4	*48.2*	*46.0*	*46.7*	44.3	43.5	*43.0*	*43.0*	*45.3*	39.9	43.0	41.2	*40.5*	*41.1*	*42.1*	43.0	42.1	41.0	*40.9*	46.4

TABLE IV

TAPPING. SQUAD III., EXPERIMENT *A*

Caffein on alternate days, with lunch

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	58.0	*57.0*	56.9	*52.9*	59.5	*58.0*	53.2	*54.1*	54.7	*56.6*	55.3	*56.5*	48.3	*54.1*	54.1	*47.9*	49.3	*48.6*	48.7	*54.2*	55.7
10:00	56.9	*58.9*	53.8	*55.3*	55.2	*54.1*	54.1	*53.4*	55.2	*56.6*	55.1	*54.5*	49.7	*46.0*	48.3	*45.2*	43.2	*43.3*	44.0	*45.3*	44.4
12:00	57.9	*67.1*	54.7	*55.0*	57.6	*57.7*	54.5	*51.9*	56.4	*56.7*	52.9	*45.8*	50.9	*47.9*	45.3	*46.9*	50.7	*42.5*	45.3	*48.3*	50.3
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	60.0	*58.7*	54.9	*55.6*	53.4	*51.3*	51.9	*50.1*	53.8	*50.6*	48.1	*51.8*	49.3	*45.8*	44.9	*43.9*	46.7	*43.1*	50.3	*44.5*	50.9
5:30	60.5	*48.7*	52.9	*53.7*	52.9	*51.2*	52.7	*50.9*	53.7	*53.0*	52.9	*45.9*	48.3	*42.5*	47.4	*45.9*	53.3	*41.5*	46.2	*42.9*	49.5

TABLE V

TAPPING. SQUAD IV., EXPERIMENT *A*

Caffein on alternate days, about 2 hours after lunch

	February																		March	
Hour	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	56.6	*55.4*	55.0	*54.9*	56.0	*53.1*	53.5	*51.6*	51.7	*53.8*	56.6	*50.9*	49.5	*53.9*	52.0	*50.6*	52.0	*53.1*	51.8	*51.0*	50.9
10:00	57.8	*51.8*	54.8	*54.8*	53.7	*55.8*	53.1	*54.9*	51.9	*52.3*	51.4	*51.4*	49.4	*51.4*	51.4	*51.2*	48.2	*52.4*	53.2	*50.8*	53.7
12:00	56.8	*56.9*	55.7	*55.0*	54.6	*52.3*	53.9	*54.2*	53.1	*53.1*	53.4	*52.8*	51.5	*51.9*	53.8	*51.4*	52.2	*52.1*	51.8	*51.3*	53.5
1:45	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	60.2	*53.4*	54.5	*54.7*	55.1	*53.8*	53.2	*49.9*	52.9	*51.0*	52.4	*50.6*	51.3	*50.0*	49.4	*48.1*	52.4	*49.3*	50.0	*51.7*	51.8
5:30	55.6	*55.1*	55.8	*55.5*	54.3	*53.8*	53.0	*49.9*	53.7	*49.5*	50.2	*51.1*	51.0	*51.8*	50.7	*48.0*	51.4	*47.9*	52.5	*49.0*	51.0

results, although the graphs which it is impossible to include show them clearly. In order to concentrate the material and thus facilitate comparison of control days with caffein days the following method of combining the records has been adopted. Although in most of the tests the first week's practise (35 trials) which is not included in these tables brought all the individuals fairly well toward a practise level of performance, there is still considerable improvement during the three weeks (105 trials) shown in the tables. Hence it is unfair to compare caffein record with either the control record of the day before or with that of the day after, alone. Nor is it satisfactory to rely on the change in performance at later trials on the same day, for here such factors as diurnal variation, fatigue, etc., enter. A more satisfactory plan is to compare each caffein record with the average of the records for the same hour on the preceding and following days. This average would give a calculated control value for the intermediate record. Comparison of this calculated measure with the actual record made on any given day will indicate the presence or absence of caffein influence. Thus on Feb. 19 at 1:45 P.M., Squad IV. took 3 gr. of caffein. At 3:10 their record was 51.5 sec. On the preceding day (Feb. 18) at the same hour their record was 52.9 sec., and on the following day (Feb. 20) 52.4 sec. The calculated record for Feb. 19 is then $(52.9 + 52.4)/2$ or 52.65 sec. But the actual record was only 51.50 sec. This is then to be interpreted as signifying 52.65–51.50 or 1.15 sec. stimulation produced by the 3 gr. of caffein. In the same way the calculated record for Feb. 21 at 3:10 for the same squad is $(52.40 + 51.30)/2$ or 51.85 sec. The actual record, after another 3 gr. dose of caffein, was only 50.60. This shows 51.85–50.60 or 1.25 sec. stimulation. Further, averaging the calculated records for the 19th and 21st we get $(52.65 + 51.85)/2$ or 52.25. But the average of the actual records made on those days is only $(51.50 + 50.60)/2$ or 51.05. The average effect of 3 gr. of caffein under the circumstances prescribed for this squad, based on two observations, is then 52.25–51.50 or 1.20 sec.

Such calculations have been made for each caffein dose for all four squads, and the average influence of the various-sized doses (two trials for each dose with Squads I., III. and IV., and three trials for each with Squad II. except for 6 gr.). These results are presented in Tables VI.–IX. In these tables the records for caffein days (italicized) parallel the records for control days and the tables show the average results of the several trials for each dose. A third column under each hour of the day indicates the difference between the two records (control days minus caffein days). After the dose has been taken a + in this column means stimulation and a — means

TABLE VI

Squad I. Tapping

	7:45			10:00			12:00		1:00		3:10			5:20	
Sug. Av.	Caff Av.	Dif.	Sug. Av.	Caff Av.	Dif	Sug. Av.	Caff Av.	Dif.	Dose	Sug. Av.	Caff Av.	Dif.	Sug. Av.	Caff Av.	Dif.
57.6	*56.2*	+ 1.4	57.1	*56.4*	+ 0.7	57.5	*56.8*	+ 0.7	S	56.3	*55.7*	+ 0.6	59.1	*55.9*	+ 3.2
54.7	*54.2*	+ 0.5	55.6	*53.5*	+ 2.1	54.2	*56.0*	— 1.8	S	55.8	*54.6*	+ 1.2	54.7	*54.4*	+ 0.3
55.3	*53.6*	+ 1.7	52.6	*54.2*	— 1.6	52.4	*53.6*	— 1.2	S	55.4	*52.6*	+ 2.8	51.8	*52.1*	— 0.3
54.3	*52.5*	+ 1.8	53.7	*51.6*	+ 2.1	52.2	*51.5*	+ 0.7	S	54.1	*51.6*	+ 2.5	51.2	*52.3*	— 1.1

TABLE VII

Squad II. Tapping

Dose	Average 1st and 2d	Average Per Cent. 3d and 4th	Average Per Cent. 5th	Average Per Cent. 3d, 4th and 5th	Cases
Sugar	45.0	100.5	97.7	99.1	11
1 gr.	48.6	98.5	96.5	97.5	3
2 gr.	44.7	97.5	96.7	97.1	3
4 gr.	42.7	100.9	96.4	98.6	3
6 gr.	42.2	94.3	96.9	95.6	1
Caffein Av. ..	44.6	97.8	96.6	97.2	10

TABLE VIII

Squad III. Tapping

7:45			10:00			12:00				3:10			5:20		
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	1:00 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
57.9	*55.0*	+ 2.9	55.7	*57.1*	— 1.4	55.0	*61.0*	— 6.0	1 gr.	56.2	*55.5*	+ 0.7	54.8	*51.2*	+ 3.6
55.2	*56.1*	— 0.9	55.4	*53.8*	+ 1.6	56.1	*54.8*	+ 1.3	2 gr.	54.0	*50.7*	+ 3.3	53.0	*51.1*	+ 1.9
53.4	*56.5*	— 3.1	53.8	*55.5*	— 1.7	53.3	*51.3*	+ 2.0	3 gr.	49.8	*51.2*	— 1.4	52.0	*49.5*	+ 2.5
51.5	*51.0*	+ 0.5	47.4	*45.6*	+ 1.8	48.1	*47.4*	+ 0.7	4 gr.	46.5	*44.9*	+ 1.6	49.2	*44.2*	+ 5.0
50.6	*51.4*	— 0.8	43.9	*44.3*	— 0.4	47.9	*43.9*	+ 4.0	6 gr.	49.6	*43.6*	+ 6.0	49.0	*42.2*	+ 6.8

TABLE IX

Squad IV. Tapping

7:45			10:00			12:00				3:10			5:20		
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	1:45 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
55.7	*55.2*	+ 0.5	55.3	*53.3*	+ 2.0	55.8	*56.0*	— 0.2	1 gr.	56.1	*54.1*	+ 2.0	55.4	*55.3*	+ 0.1
53.7	*52.4*	+ 1.3	53.0	*55.4*	— 2.4	53.9	*53.3*	+ 0.6	2 gr.	53.7	*51.9*	+ 1.8	53.6	*51.9*	+ 1.7
53.7	*52.3*	+ 1.4	51.1	*51.8*	— 0.7	53.1	*52.9*	+ 0.2	3 gr.	52.3	*50.8*	+ 1.5	51.3	*49.8*	+ 1.5
51.4	*52.3*	— 0.9	50.1	*51.3*	— 1.2	53.1	*51.7*	+ 1.4	4 gr.	50.7	*49.1*	+ 1.6	51.0	*50.2*	+ 0.8
51.6	*52.1*	— 0.5	52.1	*51.6*	+ 0.5	52.3	*51.7*	+ 0.6	6 gr.	51.1	*50.5*	+ 0.6	51.9	*48.5*	+ 3.4

retardation. But it must be remembered that before the dose has been taken the reverse holds, since the morning records of caffein days follow upon the sugar doses of the day before, and are properly control records, while the morning records of the control days are subsequent to the caffein doses of the preceding day. The tables indicate in separate columns the time and amount of the dose.[8]

Table VI. is the record of Squad I., the control, to which sugar only was given. In the table only the even days are treated as sugar days, the odd days being handled as *if they had been* true caffein days. After the sugar capsule at 1:00 P.M. there is what appears to be a stimulation at the 3:10 period for all doses. But examination of the individual records shows that this appearance is due entirely to the brisker performance of Subject XV., a woman who traveled through the tests in company with two members of Squad IV. who had really had caffein, and show considerable stimulation. There is little doubt in the mind of the experimenter that this subject was spurred on in the tapping test by the suggestions of greater speed coming from the two other subjects in the room. This appearance is then spurious and it is the only evidence of stimulation present and does not vary with the size of the dose. At 5:30 the differences between the calculated and the actual records are small and balance each other as to sign.

Squad II. took similar doses at 10:30 A.M. on each of three successive days. Hence the method of comparing actual with calculated record can not easily be applied. Instead, the 7:45 and 10:00 trials of each day have been averaged and treated as the normal records for the respective days. With these normals have been compared the average of the two trials after the dose (12:00 and 3:10) and also the final trial of the day (5:30). These latter records have been transformed into terms of per cent. of the normal for the corresponding day. Table VII. summarizes the results of this computation. Thus the average normal performance of the 11 control days is 45 sec. The average of the two trials following the sugar capsule is 100.5 per cent. of this normal, showing slight fatigue. Comparing this with the similar records after the caffein doses, we find a tendency to stimulation instead of fatigue in the latter cases, the average time of all four amounts (1, 2, 4, 6 gr.) being only 97.8 per cent. of the normal performance. With the exception of the 4 gr. doses (double the amount ever taken before and following abruptly upon three sugar days) the stimulation increases with the size of the dose. For these 4 gr. doses, however, there is slight retardation (.9 per cent.) instead. The final trials for the control days average 97.7 per cent. of the

[8] This method of presenting the data is also followed in the later chapters.

normal, indicating a tendency to superior performance at the end of the day. (This is a characteristic of the tapping test which has an interesting bearing on the problem of diurnal variation, but the matter can not be taken up in the present study.) After the caffein doses, however, this superiority of the evening performance is over 1 per cent. greater, and without exception, the average record being only 96.6 per cent. of the normal. Averaging the three tests after the dose and comparing this measure with the normal morning record for the various types of days, shows a superiority of 2 per cent. in favor of the caffein days, and shows stimulation for all sizes of caffein dose, the amount of stimulation on the whole increasing slightly with the size of the dose (97.5, 97.1, 98.6, 95.6). We may conclude then that caffein taken in the middle of the forenoon increases the speed of performance by this squad, yielding an average of 2 per cent. superiority over the speed of control days, the actual amount of stimulation depending, in part at least, on the size of the dose.

Table VIII. gives the results secured from Squad III., computed in the same way as those for Squads I. and IV. The dose here was taken at 1:00 P.M., during or immediately at the close of the lunch period. At the 3:10 test there is already evidence of stimulation after all but the three grain dose. By 5:30 the increase in speed is pronounced and increases with the size of the dose from 1.9 sec. at 2 gr. to 6.8 sec. at 6 gr. Turning to the 7:45 and 10:00 o'clock trials we find practical balance, the differences between control days and caffein days being slight and as often positive as negative. There is then, so far as these data are concerned, no evidence of any after effect, either of stimulation or retardation. We may say then that caffein administered along with food substance at lunch time produces stimulation, which (except for the 6 gr. dose) is not especially marked until the 5:30 period, when it is considerable and varies directly with the size of the dose. The amount of stimulation found here (an average of 4 sec. or about 8 per cent.) is much greater than that found with Squad II. to whom the caffein was administered in the middle of the forenoon. There is no evidence of any secondary effect up to noon of the next day, which is as far as Experiment *A* is able to trace the influence of the dose.

Table IX. shows the data from Squad IV., to whom the dose was administered on an empty stomach, two hours after lunch hour. At the 3:10 test there is at once clear evidence of about equal stimulation for all doses of caffein. At 5:30 this stimulation is still greater and tends to vary in amount directly with the size of the dose, from .1 sec. for 1 gr. to 3.4 sec. for 6 gr. On the next morning at 7:45, 10:00 and 12:00 the differences between caffein days and control

days are small and vary in sign, with no clear indication of an after effect of any kind.

The above method of treating the data from Squads I., III. and IV. proceeds on the assumption that the proper standard of performance with which the results after caffein should be compared, is the record made at a corresponding time of day after a control dose. But this is not the only standard available in our experiment. Since

TABLE X

TAPPING. SQUAD I., EXPERIMENT *A*

Ratios of performance after dose to performance before dose

Subject	Control Av.	M.V.	Pseudo-Caf. Av.	M.V.
1	1.011	.014	.985	.034
4	1.002	.057	1.015	.046
7	1.058	.101	.985	.038
15	.986	.030	.983	.044
Average	1.014	.050	.992	.040

trials were made, on both control and caffein days, both before and after the dose, it is possible to compare the work done after the dose, on any given day with the work done on that same day before the administration of the dose. Such a comparison should afford a valuable check on the conclusions based on the comparison of records after control doses with those after caffein doses. In fact such a compari-

TABLE XI

TAPPING. SQUAD III., EXPERIMENT *A*

Ratios of performance after dose to performance before dose

Subj.	Control Average	M.V.	1 gr.	2 gr.	3 gr.	4 gr.	6 gr.	Caffein Average	Dif. Per Cent.
3	1.008	.040	1.075	1.030	1.010	.930	.913		
			1.027	.900	.930	.940	.881	.963	— .045
			1.051	.965	.970	.935	.897		
			.716	.833	.930	.852	.897		
9	.934	.070	1.002	.947	.895	.970	.854	.889	— .045
			.859	.890	.913	.911	.874		
			1.038	.852	.915	.895	1.025		
14	1.018	.060	.978	.915	.919	.987	.926	.945	— .073
			1.008	.883	.917	.941	.975		
Av.	.986	.056	.972	.912	.933	.929	.915	.932	— .054

son has already been made in the case of Squad II. In tables X–XII. similar figures are given for the other squads, the data for each subject being given separately, along with the squad averages. In these

tables the average of the records before the dose is taken as the norm for the day, and with this norm is compared the average of the records after the dose, the figure given being the ratio of the latter to the former. The various types of days have been kept separate, so that the result of any dose may be compared directly with the average ratios for control days. The difference between these control ratios and the caffein ratios are also given in the final column of the tables.

TABLE XII

TAPPING. SQUAD IV., EXPERIMENT *A*

Ratios of performance after dose to performance before dose

Subj.	Control Average	M.V.	1 gr.	2 gr.	3 gr.	4 gr.	6 gr.	Caffein Average	Diff. Per Cent.
			1.025	1.040	.903	.893	.870		
5	.975	.027	.980	.943	.926	.950	.990		
			1.002	.991	.915	.921	.930	.952	—.023
			.965	1.000	.960	1.010	.903		
6	.978	.051	.970	.943	.980	.950	1.045		
			.968	.971	.970	.980	.974	.972	—.006
			1.017	.990	.905	1.090	1.000		
10	1.023	.032	1.030	.893	.960	.923	.934		
			1.023	.941	.937	1.006	.967	.975	—.048
			.925	.995	.970	.967	.910		
11	.985	.033	1.025	.933	1.088	.967	.990		
			.975	.964	1.029	.967	.950	.977	—.008
			.983	.984	.997	.945	.967		
16	1.013	.038	.986	.955	.947	.935	.965		
			.984	.969	.972	.940	.966	.966	—.047
Av.	.995	.036	.990	.967	.965	.963	.957	.968	—.027

Table X. gives the ratios for Squad I. for seven control days and the same number of pseudo-caffein days, with their M.V.'s. Subjects 1 and 7 are somewhat better on pseudo-caffein days, Subject 4 is better on control days, while Subject 15 shows no difference. The squad averages show a slight superiority on pseudo-caffein days. On the whole then the two types of days balance.

Table XI. gives the records for Squad III. All three subjects show from 4.5 per cent. to 7.3 per cent. stimulation on caffein days, the average being 5.4 per cent. stimulation for all caffein doses. The least stimulation comes from the 1 gr. dose, and the larger amounts do not differ consistently from each other. The previous conclusions concerning this squad are thus completely confirmed.

Table XII., for Squad IV., most strikingly confirms the previous conclusions concerning the effect of caffein on this squad. Without exception the 5 subjects show stimulation on caffein days, ranging in amount from .6 per cent. to 4.8 per cent. The average for the squad, for all doses, is 2.7 per cent. The averages for the various doses show the stimulation to begin with the 1 gr. dose and to increase uniformly with the size of the dose.

In the examination of the effect of caffein on the other tests it will be pointed out that the magnitude of the effect varies inversely with the body weight of the individual. The tapping test is the only exception to this rule. In this case the heaviest individuals (subjects 3, 9, 10, 14 and 16) are more stimulated than are the slighter subjects (5, 6 and 11). The tapping test is again an exception in that the squad taking the dose at the lunch hour yields the highest per cent. of stimulation. In the case of the other tests the greatest effect is shown by the squad taking the caffein in the mid-afternoon, unaccompanied by food.

Experiment *B*

The obvious defect of Experiment *A* is that the action of the dose is not tested at close range nor followed closely for a long period of time, since only five tests a day were made. The rate of action of the drug can not be made out, nor the time of persistence of the effect, nor can its secondary results be accurately determined. As evidence bearing on these points the results of the three-day intensive experi-

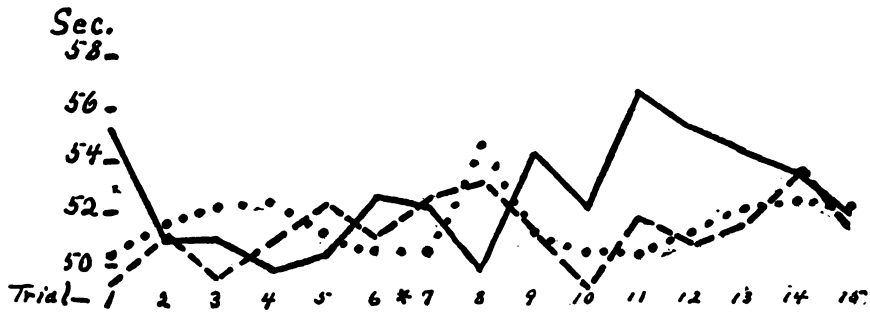


Fig. 4. Tapping Test. Experiment *B*. Squad I.

ment are here presented in the form of curves, the unit again being the total time required for the squad to complete the test. In these curves the solid line is the record for March 3, the broken line for March 4, and the dotted line for March 5. The star indicates the time of administering the dose.

Squad I. was the control. On March 3 and 4 only sugar doses

were given. The curves for these two days begin at the same point and show clear tendency to fatigue as the day goes on, dropping slightly in the latter part of the afternoon. This may be considered the normal tendency in the tapping test. On the last day (March 5) this squad was given 3 gr. capsules of caffein after the 6th trial and 2 more gr. an hour and a half after the evening meal. At the 8th test, 1.5 hours after the 3 gr. dose, this third curve rises abruptly, suggesting an initial retardation. The curve then drops to its original level and does not show the fatigue that is clearly present in the two normal curves. The afternoon and evening records are as good as or even better than those of the morning hours before the dose was taken.

FIG. 5. TAPPING TEST. Experiment *B*. Squad II.

Squad II., on the first day, took 1.2 gr. of caffein (dissolved in a glass of soda fountain syrup and carbonated water) after the 6th trial. At the 8th trial, 1.5 hr. later, the curve drops several seconds and remains low for about 2 hours, after which it rises to the normal fatigue level. On the next day the curve starts out at about the same level as before. Only a sugar capsule was given on this day, and the normal fatigue curve results, the afternoon's record being greatly inferior to that of the day before. On the last morning the curve runs on a high level. After the 6th test 2.4 gr. of caffein were given in the same way as on the first day. The curve at once descends to the lowest level of the first day, showing a gain of nearly 10 seconds. After about 2 hr. it rises again to the normal fatigue level.

Squad III. took 3 gr. of caffein in a capsule, after the 6th trial on the first day. Forty-five minutes later the curve rises abruptly, falling to the original level in 1.5 hr., after which it follows a fairly uniform level with no evidence of fatigue. On the following day the

curve starts at about the original level, rises slightly as the day goes on and then strikes the morning level again. Only sugar was given on this day. There is no evidence of any secondary result of the first day's caffein. The last day was still a control day. There is here only the normal slight tendency to fatigue in the latter part of

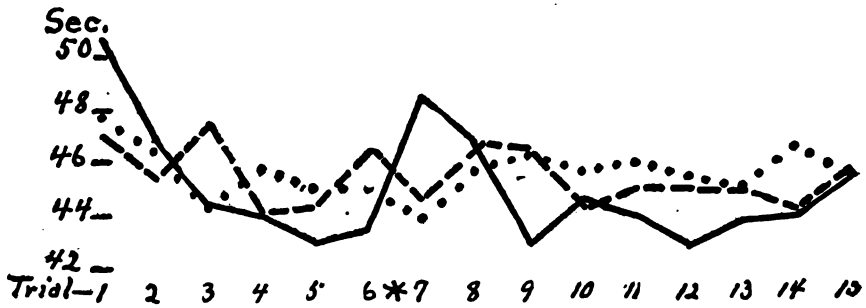


FIG. 6. TAPPING TEST. Experiment *B*. Squad III.

the day, with no evidence of either benefit or disaster as a consequence of the caffein of the first day. The afternoon and evening records on the caffein day remain unequalled by the performance of either of the succeeding days, but the result of the dose seems to have been first a retardation, then counteraction of the tendency to fatigue in the afternoon.

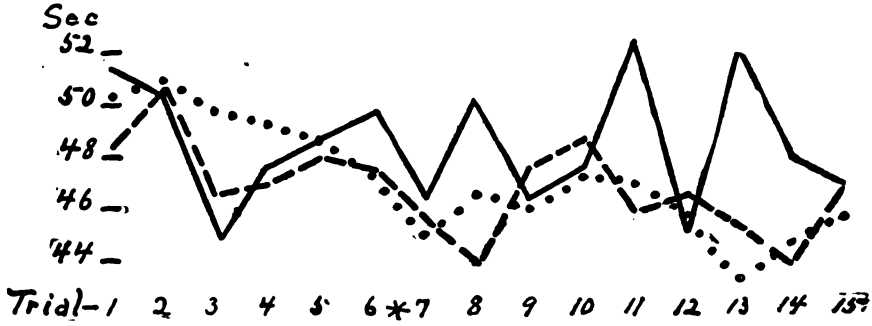


FIG. 7. TAPPING TEST. Experiment *B*. Squad IV.

Squad IV. were given 6 gr. capsules of caffein on the first day and sugar capsules on the days following. The effect of this large dose, taken as it was after several successive control days, seems to have been to produce a great irregularity of performance, six of the subsequent trials breaking all but one of the morning records and

three of them being among the poorest records of the day. The general tendency is toward stimulation, but this stimulation is mixed with an irregularity of performance that resembles the first effect of retardation observed in Squads II. and III. The effect begins as in the other cases, about three quarters of an hour after the dose, and in this case persists about 4.5 hours. On the following day the morning curve behaves much as that of the first day, there being no indication of secondary effect from the first day's dose. As the day goes on the curve is much more regular than that of the preceding day and follows an intermediate course with respect to level. Much the same thing is true of the third day's work.

Experiment C

In this experiment, which lasted 7 days, 12 of the subjects comprised a single squad, all receiving the same doses, fifteen minutes before the beginning of each afternoon test. On two days no dose at all was given; on two days glasses of soda fountain syrup containing no caffein; on three days the same syrup with caffein in solution. (For full particulars see Chapter 2.) The results of this experiment, for the tapping test are given in Table XIII. In this table, instead of platting efficiency curves for the different hours and

TABLE XIII

Tapping. Experiment C. 15 Subjects

Type of Day		Av. 8 Trials Before Dose M.V.		Av. 2 Trials After Dose M.V.		Ratio of Last 2 to First 8 M.V.	
Blank	Feb. 6	64.1	7.1	66.3	8.0	1.034	.057
days	11	64.0	8.9	65.5	9.1	1.023	.044
				Av. ratio, blank days ...		1.029	.050
Plain	7	62.8	10.0	61.6	9.5	.971	.049
syrup	9	63.4	7.9	64.1	8.9	1.011	.040
				Av. ratio, syrup days ...		.991	.044
Caffein							
1.2 gr.	8	62.9	7.2	61.2	8.8	.973	.045
3.6 gr.	10	60.3	10.4	61.8	8.9	1.025	.037
6.0 gr.	12	65.1	8.5	60.7	7.9	.932	.044
				Av. ratio, caffein days ..		.976	.042

conditions, the records of the first three periods of each day are averaged to secure the individual's normal efficiency for that day, and with this normal is compared the average of the last two trials of the same day, these latter records having been made after the administration of the dose. The table gives the averages and their

M.V.'s, and the ratios and their M.V.'s, with final averages for each type of day, for the 12 subjects treated as a single squad. Thus 102.9 means that the time of the average performance after the dose was 102.9 per cent. of that of the average performance before the dose. When this per cent. is greater than 100 it indicates fatigue, while a per cent. less than 100 indicates stimulation. Comparison of any two per cents., whether above or below 100 will indicate relative fatigue or relative stimulation. Each final average in the table is the average of 120 trials in the cases of the control days and of the plain syrup days, and of 180 trials in the case of the caffein days.

Referring now to this table, there is seen to be 2.9 per cent. fatigue on control days, .9 per cent. absolute stimulation on syrup days, and 2.4 per cent. absolute stimulation on caffein days. Subtracting the .9 per cent. stimulation yielded by the syrup and carbonated water alone gives a net caffein stimulation of 1.5 per cent. Comparison of these results with the 2.9 per cent. fatigue present on control days indicates a relative stimulation of 3.8 per cent. from the syrup alone, and a relative stimulation of 5.3 per cent. from the syrups with caffein, or a net caffein stimulation of 4.4 per cent.

Summary

Summarizing the results of the three experiments we find:

1. That the typical caffein effect on a motor process such as that involved in the tapping test seems to be a stimulation, which is sometimes preceded by a brief and slight initial retardation.

2. The magnitude of this stimulation (*a*) varies directly with the size of the dose, and (*b*) is relatively slight when the caffein is taken in the forenoon.

3. The effect begins in from 45 to 90 minutes after the administration of the dose, the period being shorter for large doses and longer when the dose is taken along with food.

4. The effect persists for from one to two hours for doses of 1 to 3 gr. and as long as 4.5 hours for 6 gr.

5. There is no secondary or after effect shown within the 72 hrs. over which the intensive doses were traced.

CHAPTER V

The Influence of Caffein on the Steadiness Test

The steadiness test, although not without a certain psychological significance in some connections, is exceedingly difficult to conduct in a satisfactorily rigorous manner. The performance itself, on the part of the individual tested, is easily influenced by factors foreign to the one over which the experimenter may be exercising control. The excitement of taking any kind of dose, or of having accidentally begun in a bungling manner, laughing, a coughing spell, changes in respiration, noises from the street or from adjoining apartments, conspire to produce irregularity and unsteadiness which bear no relation to the influence of caffein. If the hole in which the stylus is inserted is made small enough to betray slight tremors the subject's poise is disturbed by the first few contacts. This was especially true in the present experiment, since the electric counter which registered the contacts was in the room with the rest of the apparatus and every click of the magnet was audible. The use of a counter is in itself most unsatisfactory since faint contacts may fail to actuate the magnet. A longer rod should perhaps be used in order to magnify the amplitude of these small movements. Further, the apparatus described registers at most only movements in the horizontal plane. But it was quite out of the question to employ a more elaborate procedure in the present experiment, and the rather crude method used was adopted in the hope that it might at least afford suggestions bearing on a problem which must otherwise have been entirely ignored.

Experiment *A*

The results for the different squads in Experiment *A* are given in the following tables, in which the records for the various hours on control days have been averaged and may be compared with similar averages of the records after the several amounts of caffein. A separate column indicates the hour and character of the dose. The M.V.'s of all these averages are large, usually about 50 per cent. of the averages themselves. The M.V.'s for Squad I. are given as typical. The variabilities of the other squads are not indicated, since the differences between the average records are only in a few cases large enough to suggest caffein influence.

TABLE XIV

STEADINESS. SQUAD I. EXPERIMENT *A*

Average number of contacts in one minute

Hour		7:45	10:00	12:00	Dose 1:00	3:10	5:30	Cases
Control days	Av.	2.45	2.31	3.66	Sugar	3.89	4.82	10
	M.V.	1.61	1.17	2.94		2.07	2.34	
Pseudo-caffein days	Av.	2.80	2.78	1.88	Sugar	3.00	4.16	10
	M.V.	2.00	1.92	.96		1.33	1.54	

TABLE XV

STEADINESS. SQUAD II. EXPERIMENT *A*

Hour	7:45	10:00	Dose 10:30	12:00	3:10	5:30	Cases
Av.	2.62	1.13	Sugar	1.57	1.50	1.32	10
Av.	2.21	1.55	1–2 gr.	1.43	2.58	3.00	6
Av.	1.50	0.30	4–6 gr.	0.80	2.90	1.10	4

TABLE XVI

STEADINESS. SQUAD III. EXPERIMENT *A*

Hour	7:45	10:00	12:00	Dose 1:00	3:10	5:30	Cases
Av.	1.74	1.83	1.16	Sugar	1.47	1.34	10
Av.	3.17	1.82	2.35	1–2 gr.	1.70	2.07	4
Av.	1.70	1.17	0.50	3–4 gr.	1.50	1.10	4
Av.	0.50	0.40	0.60	6 gr.	0.70	1.80	2

TABLE XVII

STEADINESS. SQUAD IV. EXPERIMENT *A*

Hour	7:45	10:00	12:00	Dose 1:45	3:10	5:30	Cases
Av.	2.64	2.58	3.68	Sugar	2.65	2.98	10
Av.	1.85	1.90	2.75	1–2 gr.	2.00	4.60	4
Av.	2.70	2.75	3.45	3–4 gr.	2.75	3.30	4
Av.	0.60	1.30	1.70	6 gr.	4.30	12.10	2

Table XIV. gives the records for the control squad. There is a uniform tendency on both sets of days for the averages to increase in magnitude at the 3:10 and 5:30 periods. This is apparently a normal fatigue effect, since it is greatest at 5:30 and only slightly present at 3:10. Squad II., Table XV., who took caffein in the mid-forenoon on successive days, shows no similar tendency on control days. Even on the caffein days there is only a slight tendency, which is more marked after small doses than after large. Squad III. (dose with lunch) make much steadier records in the afternoons of control days than in the forenoons. After 1–4 gr. doses this tendency is still suggested by the averages, with no loss of steadiness after the doses.

Only on the days of the 6 gr. dose is the afternoon record inferior to that of the forenoon. On these days there is surprising steadiness (the average being only about 0.5 contacts in a minute) until the 5:30 test, 4–5 hours after the administration of the dose, when the average rises to 1.8. Squad IV., taking doses on an empty stomach at 1:45 P.M., shows uniform performance throughout the day after control capsules. After 1–4 gr. doses of caffein there is a suggestion of unsteadiness at the 5:30 period. After 6 gr. there is clear impairment even at the 3:10 test, the records rising from an average of 1.2 contacts in the forenoon to 4.3 at 3:10 and to 12.1 at 5:30. The most striking effect, as in the case of Squad III., is several hours after the dose.

EXPERIMENT *C*

In Experiment *C*, the results of which are to be found in Table XVIII., an attempt was made to secure closer measures by using a smaller hole on the steadiness board (4.5 mm. instead of 6 mm. as in Experiment *A*). Each result given in the table is the average of 12 records each hour of each day, since the whole group of 12 subjects here comprised a single squad. Blank days (no dose) and plain syrup days both show uniform performance at the successive trials. After 1.2–3.6 gr. of caffein the 5:30 record is slightly inferior. After the 6 gr. dose, however, the effect is enormous, the record falling from a morning average of 9.7 contacts to 18.4 at 3:10 and 28.0 at 5:30.

TABLE XVIII

STEADINESS. EXPERIMENT *C*

Doses just preceding 3:10 and 5:30 tests

Hour		7:45	10:00	12:00	3:10	5:30
2 blank days	Av.	11.0	10.6	10.5	12.4	11.4
2 syrup days	Av.	13.0	10.5	9.5	11.5	10.5
2 caffein days, 1.2–3.6 gr., with syrup ..		12.2	11.2	11.5	10.6	13.0
1 caffein day, 6 gr. with syrup		8.5	11.1	9.4	18.4	28.0

EXPERIMENT *B*

The results of the three-day intensive Experiment *B*, in which the small hole was also used, are given in Tables IX.–XXI. Squad I. shows no great variation during the 15 successive trials on each of the control days. But after the 3 gr. dose of caffein, taken after the 6th trial on March 5th, an increase in contacts of 100 per cent. comes at once, falling off then until the 2 gr. dose was given at a later hour,

TABLE XIX

STEADINESS. EXPERIMENT *B*. MARCH 3

Giving the average for each squad, at each of the 15 trials

Trials	1	2	3	4	5	6	Dose	7	8	9	10	11	12	13	14	15
Squad I.	26.7	22.0	21.3	19.3	11.0	25.3	Sugar	19.0	27.7	14.0	23.7	16.7	16.0	22.6	37.6	22.3
II.	23.5	7.5	26.0	17.0	19.0	15.0	1.2 gr.	12.0	54.0	44.0	28.5	25.5	25.0	19.0	16.5	12.0
III.	16.6	11.8	20.3	10.0	6.2	7.6	3 gr.	9.4	6.8	9.4	13.6	19.0	7.8	9.8	10.2	7.8
IV.	16.7	14.3	16.0	23.0	16.0	19.0	6 gr.	13.3	19.0	12.0	18.0	22.0	22.0	27.3	27.3	11.0

TABLE XX

STEADINESS. EXPERIMENT *B*. MARCH 4

Trials	1	2	3	4	5	6	Dose	7	8	9	10	11	12	13	14	15
Squad I.	31.3	17.0	24.3	11.7	23.0	25.3	Sugar	18.3	25.3	19.0	27.3	24.7	26.7	26.3	15.7	14.0
II.	14.5	10.5	16.5	26.0	27.5	25.0	Sugar	48.5	24.0	15.5	10.5	28.5	26.0	43.5	25.5	19.0
III.	18.0	11.0	8.6	7.8	14.8	8.0	Sugar	12.4	5.6	11.2	8.8	14.8	9.4	5.2	6.0	4.0
IV.	12.7	12.3	10.7	12.0	9.7	10.7	Sugar	6.0	4.3	14.0	7.7	22.0	14.3	8.7	10.0	9.0

TABLE XXI

STEADINESS. EXPERIMENT *B*. MARCH 5

Trials	1	2	3	4	5	6	Dose*	7	8	9	10	11	12	13	14	15
Squad I.	23.0	18.0	20.3	11.3	18.7	34.7	3 gr.	40.0	40.6	35.3	33.3	31.7	23.0	31.7	27.7	14.7
II.	12.0	20.5	13.5	19.5	17.0	8.0	2.4 gr.	3.0	14.5	27.0	11.5	28.5	13.5	21.5	11.5	19.5
III.	5.0	9.2	12.6	9.4	14.4	9.2	Sugar	13.6	9.6	7.8	7.6	16.0	4.6	6.0	4.8	4.6
IV.	30.0	8.3	8.0	13.3	7.6	6.0	Sugar	8.0	6.7	7.0	5.0	14.0	10.3	3.7	7.3	8.0

* Squad I. also took 2 gr. after the 12th trial.

when it rises again. This abrupt effect is quite in contrast to what was found in Experiments *A* and *B*. The discrepancy may perhaps be due to differences in the conditions of the experiment. There was considerable strain involved in the work of these three intensive days, and this caffein day was the third day of that strain. The other tests, however, show no such difference between these days and those of the other experiments. Squad II. shows great irregularity from which no conclusion whatever can be drawn. There is an abrupt rise after each of the small caffein doses but a similar rise is also present immediately after the control dose. We have evidently to deal here with factors foreign to the caffein influence. The behavior of Squad III. after the 3 gr. caffein dose is not different from that after the control doses. Squad IV., after the 6 gr. dose of caffein, shows a marked decrease in steadiness, which does not show itself, however, until about three hours after the dose was taken.

Summary

All three experiments then yield fairly consistent results, in spite of their unsatisfactory technique. After 1–4 gr. of caffein a slight nervousness ensues, which is not apparent until several hours after the dose. After 6 gr. there is pronounced unsteadiness, which begins to be manifested within an hour or so after the dose, but which is still greater after 3–4 hours. Such unsteadiness as is produced is less clearly shown when the caffein is taken in the forenoon or at lunch time than when it is administered in the afternoon, unaccompanied by food. These results are exactly paralleled by the influence of caffein on the quality and quantity of sleep, and suggest an intimate relationship between the measurable tremor produced by caffein on a given muscle group and the evident nervous excitement that is responsible for the insomnia produced by large doses of the same substance.

CHAPTER VI

The Coordination Test

The three motor tests, tapping, steadiness and coordination, required more time for their performance than any other group of tests in charge of a single assistant. In order to avoid delay in the intensive experiment and in the experiment with syrups the coordination test was omitted. This test was chosen for omission for the further reason that in the preliminary working up of the data there seemed to be no indication of any considerable caffein influence. Concerning the time of action, the persistence time, and the presence or absence of secondary effect, therefore, nothing can be stated, in the absence of intensive experiments. As for the value of the test as a means of determining the presence of drug influence, the apparatus in its present form is hardly refined enough to reflect small disturbances of coordination. Skill in performing the test was frequently found to vary for quite unaccountable reasons; often much depends on beginning luckily and striking a favorable rhythm. Further, the measurement of time of performance alone gives no information concerning the precise character of the drug influence—whether it affects speed only, or also actual accuracy, can be known only from observation of the subject's movements on the part of the experimenter. The amounts of the departures from the center of the target are unmeasured, except in so far as they are reflected in the time of recovery which goes to swell the total time of performance.

But in spite of the facts just mentioned, the test does show certain definite suggestions as to the influence of caffein on such coordinations as are involved in performing this three-hole test. These suggestions are further confirmed by the close agreement of the results here obtained, with the results of the experiment on skill in typewriting, a somewhat similar coordination process, though a much more complicated one.

A test involving processes somewhat similar to those used in this coordination test was used by Rivers in his study of the influence of caffein on fatigue. The following quotations are from his report of that experiment.

"The only other research on caffein which I have to record is one carried out in conjunction with Mr. McDougall, using his method of measuring fatigue of attention by estimating the accuracy of aim when dots are made to pass rapidly

through a slit. The work with caffein was done every morning at eight o'clock. The experiment lasted for nine successive days, on three of which a dose of 0.3 gram of citrate of caffein was taken ten minutes before beginning to work. On the other six mornings were taken doses of two control mixtures, which to both of us were quite indistinguishable from that containing the caffein.

"In the first period the number of hits on the caffein days comes out midway between those for the two groups of control days, while in the second period the caffein days are decidedly superior to either group of control days. This superiority of the caffein days is not due to any effect of practise, for the order of the days was varied, and the experiment was only begun after preliminary practise, so that the amounts do not show any definite increase as the result of practise during the nine days that the experiment lasted. The experiment in my own case was carried out on the same days and on exactly the same lines as that of Mr. McDougall, and it agrees with his in showing no indication of a caffein-effect in the first period, but a definite increase in the second."

The following table is a summary of the results of this experiment of Rivers and McDougall.

	McDougall		Rivers	
Number of Hits on	1st Period	2d Period After ¼ Hr.	1st Period	2d Period After ¼ Hr.
Caffein days	1,576	1,571	1,459	1,460
1st control	1,606	1,424	1,511	1,338
2d control	1,646	1,486	1,602	1,421

It should be noticed, in comparing the results of these experiments with those yielded by the coordination test reported in the present chapter, that Rivers used caffein citrate instead of caffein alkaloid. The dose was 0.3 gramme, which is equivalent to 2.5–3 grains of the alkaloid, in strength. The stimulation which was present in Rivers' experiment will be seen to be present in the coordination test, *but only for the smallest doses* (1–2 grains of caffein alkaloid). When the dose exceeds this amount, the coordination test shows retardation instead of stimulation, as does the typewriting test as well.

Experiment *A*

The results for Experiment *A* are given in the following tables, in which the records are presented in the same way as were those of the tapping test.

Squad I. (control) shows no difference after the dose, between the pseudo-caffein days and the remaining days. The differences balance in magnitude and direction, save that at 5:30 the signs change from + to —, while at 7:45 the +'s predominate. This gives a curious false appearance of retardation on mornings after the pseudo-caffein doses.

Squad II. shows the later periods of the day to be about 3.5 per

TABLE XXII

THREE-HOLE TEST. SQUAD I., EXPERIMENT *A*

	February																		
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
7:45	64.5	65.2	60.6	63.2	59.2	53.7	56.5	56.2	53.0	55.5	55.1	55.0	55.5	54.1	55.7	52.2	50.2	53.9	56.6
10:00	63.6	61.5	55.9	59.7	56.7	54.4	54.9	53.9	54.2	53.7	56.3	58.2	53.2	49.9	51.6	52.9	51.3	52.7	51.2
12:00	61.8	61.9	58.0	58.3	55.8	52.0	52.6	52.6	52.7	66.3	53.2	54.5	55.4	50.2	52.5	46.6	49.1	53.9	52.4
1:00	Dose, sugar doses only, daily.																		
3:10	62.5	61.8	53.3	57.0	57.2	53.2	51.5	50.3	55.0	53.3	53.8	55.7	54.5	52.3	49.9	51.6	54.0	57.0	53.6
5:30	64.0	62.3	60.9	59.5	62.4	55.0	58.9	52.3	53.9	54.5	54.8	53.4	53.6	52.5	50.0	53.9	54.6	56.1	52.5

TABLE XXIII

THREE-HOLE TEST. SQUAD II., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	69.5	66.5	*60.3*	*66.2*	*63.1*	57.2	54.5	*55.4*	*52.7*	*60.5*	64.3	56.0	53.7	*52.3*	*52.6*	*51.1*	54.9	52.9	50.9	*52.5*	53.6
10:00	62.8	58.1	*59.8*	*56.8*	*55.8*	51.1	54.7	*48.8*	*53.0*	*40.8*	52.4	54.1	56.1	*52.5*	*52.1*	*48.2*	51.0	52.4	51.0	*49.8*	53.5
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*4 gr.*	*4 gr.*	*4 gr.*	S	S	S	*6 gr.*	S
12:00	62.9	61.4	*56.4*	*58.9*	*53.1*	50.1	52.0	*52.0*	*51.1*	*54.0*	52.7	52.8	47.5	*52.1*	*51.2*	*51.1*	53.1	50.9	55.4	*47.4*	53.5
3:10	67.3	59.0	*56.3*	*56.1*	*56.0*	54.9	48.3	*61.0*	*49.1*	*55.4*	55.0	53.5	49.8	*53.7*	*52.5*	*52.3*	48.1	52.7	54.9	*51.7*	50.6
5:30	65.8	62.3	*59.1*	*62.0*	*58.3*	61.8	55.0	*52.0*	*50.9*	*51.4*	56.4	53.1	52.1	*54.0*	*53.2*	*53.7*	54.4	52.7	51.4	*51.4*	54.0

TABLE XXIV

THREE-HOLE TEST. SQUAD III., EXPERIMENT *A*

	February																		March:	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	57.6	*55.0*	51.3	*51.5*	53.6	*51.7*	50.1	*49.2*	48.0	*54.7*	51.0	*50.3*	53.7	*50.5*	49.9	*50.8*	49.9	*48.7*	49.6	*50.3*	59.3
10:00	52.8	*54.7*	50.7	*49.1*	52.1	*47.2*	48.0	*49.2*	52.4	*50.2*	51.9	*50.3*	53.1	*44.8*	45.4	*52.7*	48.6	*46.5*	47.1	*45.7*	49.3
12:00	53.9	*51.6*	50.4	*54.5*	50.9	*45.7*	48.9	*45.7*	48.1	*48.7*	50.4	*50.1*	50.2	*47.7*	47.5	*49.7*	47.3	*47.4*	50.1	*45.7*	47.0
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	54.5	*57.0*	50.5	*53.5*	54.2	*49.0*	51.0	*50.2*	51.4	*48.6*	49.1	*54.4*	48.1	*48.0*	48.9	*48.9*	48.2	*50.0*	48.8	*49.6*	50.3
5:30	51.4	*54.7*	57.5	*51.1*	53.7	*49.1*	51.7	*48.7*	49.1	*52.0*	50.7	*48.4*	49.1	*50.1*	49.9	*52.1*	53.3	*48.9*	52.7	*53.1*	50.3

TABLE XXV

THREE-HOLE TEST. SQUAD IV., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	64.3	*65.6*	62.7	*61.0*	55.4	*55.7*	55.4	*55.0*	56.0	*53.6*	58.7	*52.4*	56.1	*52.0*	52.6	*52.4*	53.1	*51.7*	57.6	*54.4*	55.5
10:00	64.0	*61.0*	54.3	*57.2*	57.0	*54.7*	56.2	*53.4*	50.9	*53.6*	55.1	*57.2*	53.5	*51.9*	53.4	*50.0*	53.0	*55.0*	52.7	*49.2*	52.9
12:00	63.5	*63.0*	57.4	*55.4*	57.5	*55.7*	53.8	*54.0*	55.6	*54.8*	54.4	*51.5*	54.4	*52.4*	52.3	*52.0*	50.2	*53.4*	52.6	*53.5*	52.2
1:45	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	66.4	*59.0*	59.5	*56.8*	59.0	*54.7*	52.4	*49.0*	52.6	*54.2*	53.4	*51.0*	49.9	*52.0*	49.1	*47.9*	51.8	*53.0*	51.6	*54.2*	52.0
5:30	63.6	*61.8*	60.7	*56.9*	57.6	*56.8*	51.6	*52.0*	51.6	*54.7*	52.8	*52.8*	51.6	*54.6*	52.1	*52.7*	53.3	*55.0*	51.7	*54.4*	52.1

TABLE XXVI

Coordination. Squad I

Sug. Av.	7:45 Caf? Av.	Dif.	Sug. Av.	10:00 Caf? Av.	Dif.	Sug. Av.	12:00 Caf? Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf? Av.	Dif.	Sug. Av.	5:30 Caf? Av.	Dif.
61.3	64.2	— 2.9	58.1	60.6	— 2.5	58.4	60.1	— 1.7	S	56.6	59.4	— 2.8	62.1	60.9	+ 1.2
56.4	55.0	+ 1.4	55.2	54.2	+ 1.0	54.0	52.3	+ 1.7	S	53.9	51.8	+ 2.1	58.5	53.7	+ 4.8
59.7	55.2	+ 4.5	55.1	56.0	— 0.9	53.7	55.4	— 1.7	S	53.8	54.5	— 0.7	54.2	54.0	+ 0.2
54.3	53.2	+ 1.1	52.0	54.6	— 2.6	55.9	48.4	+ 7.5	S	56.3	52.0	+ 4.3	52.0	53.2	— 1.2
54.6	52.8	+ 1.8	51.3	51.8	— 0.5	52.0	51.7	+ 0.3	S	53.9	55.4	— 1.5	53.4	55.6	— 1.2

TABLE XXVII

Coordination. Squad II

Dose	Average 1st and 2d Normal	Third Trial Per Cent. of Normal	Fourth Trial Per Cent. of Normal	Fifth Trial Per Cent. of Normal	Average 3d, 4th and 5th Per Cent. of Normal	Cases
Sugar Av.	57.2	94.9	94.9	99.8	96.5	11
Caffein 1 gr.	60.2	93.0	93.0	99.1	95.0	3
Caffein 2 gr.	51.8	101.1	106.5	99.2	102.3	3
Caffein 4 gr.	52.0	99.0	101.0	103.0	101.0	3
Caffein 6 gr.	51.2	92.5	100.9	100.3	97.9	1
Caffein Av.	53.8	96.4	100.4	100.4	99.1	10

TABLE XXVIII

COORDINATION. SQUAD III

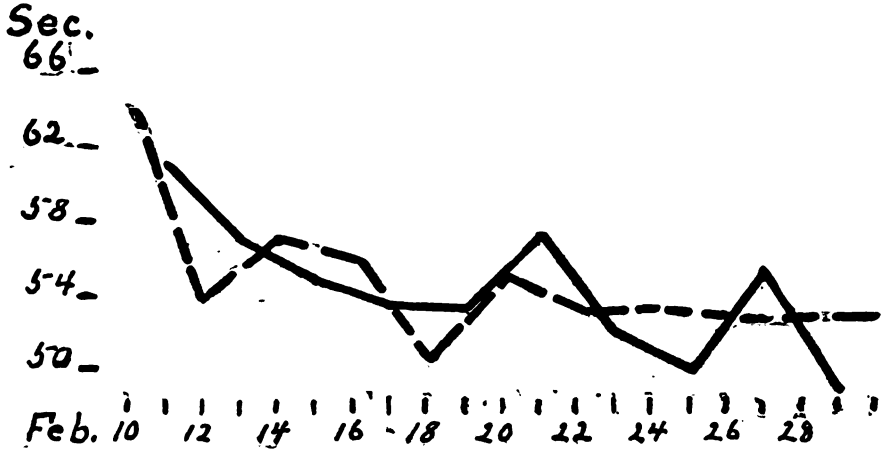
Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:20 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:30 Caf. Av.	Dif.
53.5	53.3	+ 0.2	51.4	51.9	— 0.5	51.5	53.1	— 1.6	1 gr.	52.5	55.3	— 2.8	55.3	52.9	+ 2.4
50.5	50.5	0.0	49.9	48.8	+ 1.1	49.2	45.7	+ 3.5	2 gr.	51.9	49.6	+ 2.3	51.6	48.9	+ 2.7
50.8	52.5	— 1.7	52.4	50.3	+ 2.1	49.8	49.4	+ 0.4	3 gr.	49.5	51.5	— 2.0	47.4	50.2	— 2.8
50.7	50.7	0.0	48.2	48.8	— 0.6	48.2	48.7	— 0.5	4 gr.	48.6	48.5	+ 0.1	50.6	51.1	— 0.5
52.1	49.5	+ 2.6	48.0	46.1	+ 1.9	48.7	46.6	+ 2.1	6 gr.	49.6	49.8	— 0.2	52.2	51.0	+ 1.2

TABLE XXIX

COORDINATION. SQUAD IV

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:20 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:45 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:30 Caf. Av.	Dif.
61.3	63.3	— 2.0	57.6	59.1	— 1.5	59.0	59.2	— 0.2	1 gr.	61.1	57.9	+ 3.2	60.7	59.4	+ 1.3
55.6	55.4	+ 0.2	55.2	54.1	+ 0.9	55.2	54.9	+ 0.3	2 gr.	54.1	51.9	+ 2.2	53.1	54.4	— 1.3
57.4	53.0	+ 4.4	53.6	55.4	— 1.8	54.7	53.7	+ 1.0	3 gr.	52.4	52.6	— 0.2	52.2	53.8	— 1.6
53.6	52.2	+ 1.4	53.4	51.0	+ 2.4	52.4	52.2	+ 0.2	4 gr.	50.0	45.0	+ 5.0	52.3	53.7	— 1.4
54.9	53.1	+ 2.8	52.8	52.1	+ 0.7	51.9	53.3	— 1.4	6 gr.	51.8	53.6	— 1.8	52.2	54.7	— 2.5

cent. superior to the normal for the control days, while the average of all the caffein days is about the same at the first trial after the dose, but becomes .4 per cent. inferior as the day goes on, an average retardation of 4 per cent. as compared with control days. But the various sized doses do not produce quite the same effect. The 1 gr. dose seems to yield slight stimulation at all later trials, from 1.9 per cent. at the 3d and 4th trials to .7 per cent. at the last. The 2 gr. dose, however, produces immediate inferiority over control days of 6.2 per cent. at the 3d, and 11.6 per cent. at the 4th, the retardation having disappeared at the 5th trial. The 4 grains produce retardation for all three trials, as compared with control days, and for both



COORDINATION TEST. EXPERIMENT A. SQUAD IV

Broken line represents control days and solid line caffein days. Dose taken in mid-afternoon, on empty stomach.

FIG. 8. 10:00 A.M. No difference shown.

the 2 gr. and 4 gr. amounts the average performance after the dose is inferior to the normal instead of superior, as on control days. The 6 gr. dose produces at the next trial, the best record in the table, a superiority of 7.5 per cent. over the normal and of 2.4 per cent. over the corresponding record for control days. At the following trials, however, there is both absolute and relative retardation. The average for all caffein doses shows, at the successive trials after the dose, an inferiority of 1.5 per cent., 5.5 per cent. and .5 per cent. as compared with the corresponding records for control days. Generally speaking, for this squad small doses stimulate for the rest of the day; medium doses retard for the next two trials, while the large dose first stimulates and then retards.

Squad III. shows balanced records throughout, with the possible exception that at 5:30 there seems to be an effect similar to that noted with Squad II. Small doses (1–2 gr.) stimulate, medium (3–4) retard, while 6 gr. yields evidence of slight initial stimula-

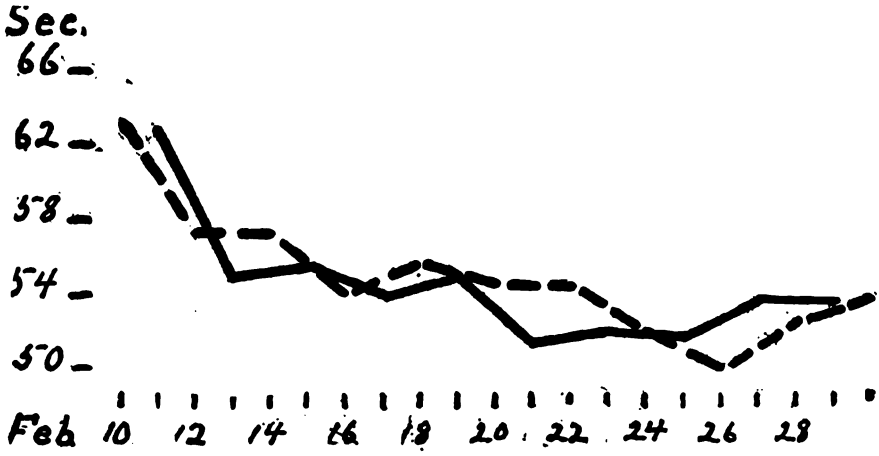


FIG. 9. 12:00 M. No difference shown.

FIG. 10. 3:10 P.M. About one hour after dose. No difference.

tion (remembering that the drug action is doubtless retarded here by the fact that the dose was taken at lunch time, along with food substance).

Squad IV., at 3:10, shows stimulation for 1–4 gr. At 5:30 this effect persists for 1 gr. but all other amounts show retardation. For 6 gr. this retardation was already present at 3:10. At 10:00 and 12:00 the differences balance, but at 7:45 there is the same appearance of retardation that was noted in the case of Squad I., the control squad. Were it not for this latter fact one would be inclined to take the figures as evidence of continued retardation on the mornings after caffein days. Perhaps, indeed, the conclusion that small amounts of caffein stimulate should be pronounced with some caution, for a similar relation of the figures occurs at the 5:30 test for Squad I. as a result of sugar doses only. But that this again is a false appearance is indicated by the fact that at the preceding trial, 2 hours after the dose, no such relation is present, with this control squad, while in Squads II., III. and IV. the two trials (3:10 and 5:30) are consistent. The following curves show for Squad IV. the

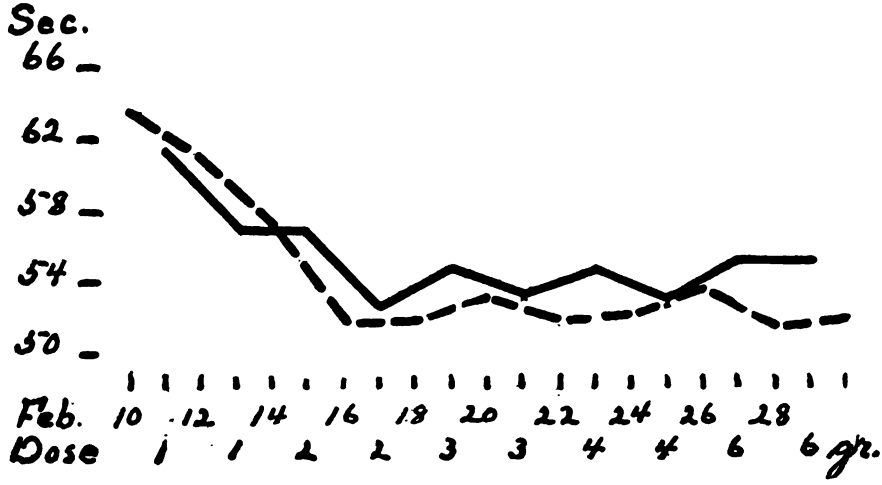


FIG. 11. 5:30 P.M. Evidence of retardation on caffein days, for doses larger than 1 grain.

records for the two trials before and the two after the doses, on each of the 21 days. As in the case of the tapping test, the broken line represents the records for control days and the solid line those for caffein days. The curves for the 10:00 and 12:00 periods show no difference between control and caffein days. But at 3:10 the stimulation from 1–2 gr. is indicated, while at 5:30 there is uniform retardation for amounts larger than 1 gr.

Another way of treating these data is to compare the performance after the caffein dose with the performance of the earlier trials of the same day, instead of with the records for corresponding hours on

control days. Thus if the average of the trials before the dose be considered the standard for the day, the ratio of the trials after the dose to this standard, will give, when ratios for control days and for caffein days are compared, a measure of the caffein influence if such is present. The results from the Three Hole test, when thus treated, are given in Tables XXX.–XXXIV. The ratios for Squad I. (Table

TABLE XXX

THREE-HOLE TEST. SQUAD I., EXPERIMENT *A*

Showing ratio of performance after dose to performance before dose

Subj.	Control Days Av.	M.V.	Pseudo-caf. Days Av.	M.V.
1	1.010	.040	1.010	.034
4	.992	.048	.991	.070
7	.973	.029	.995	.040
15	.989	.045	.985	.050
Average	.991	.040	.995	.048

TABLE XXXI

THREE-HOLE TEST. SQUAD II., EXPERIMENT *A*

Showing the ratio of the 12:00 and 3:10 records (Av.) to the performance before the dose at 10:30 A.M.

Subj.	Control Average	M.V.	Caffein 1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.	Av. of 1 and 2 Gr.	Av. of 4 and 6 Gr.
8	.977	.052	.959	.050	.919	.030	.990	.040	1.024	.939	1.007
12	.986	.049	.941	.040	.991	.023	1.017	.040	.910	.966	.964
13	.936	.046	.953	.016	.943	.020	1.026	.016	.920	.948	.973
Av.	.969	.049	.951	.035	.951	.024	1.011	.032	.951	.951	.981

Difference between Control Av. and final Caffein Av. ..... —.018 +.012

TABLE XXXII

THREE-HOLE TEST. SQUAD II., EXPERIMENT *A*

Showing ratio of 5:30 test to performance before dose at 10:30 A.M.

Subj.	Control Average	M.V.	Caffein 1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.	Av. of 1 and 2 Gr.	Av. of 4 and 6 Gr.
8	1.047	.063	1.035	.053	.960	.043	.998	.046	1.041	.997	1.019
12	.951	.045	.928	.026	1.020	.043	1.053	.073	.994	.974	1.023
13	1.028	.079	1.079	.020	.991	.073	1.076	.043	.978	1.035	1.027
Av.	1.008	.062	1.014	.033	.990	.053	1.042	.054	1.004	1.002	1.023

Difference between Control Av. and Caffein Av. ..... —.006 +.015

XXX.) on caffein and control days, do not differ. This holds for all four subjects as well as for the final average for the squad.

In the case of Squad II., the results for the first two trials after the dose have been computed in one table, and the results of the

TABLE XXXIII

THREE-HOLE TEST. SQUAD III., EXPERIMENT *A*

Showing ratio of records after dose (Av. of 3:10 and 5:30 trials) to record before dose (Av. of 8:00, 10:00 and 12:00 trials)

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	Caffein 3 Gr.	4 Gr.	5 Gr.	Average 1 and 2 Gr. Also Difference Between These and Control Average	Average 4 and 6 Gr. Also Difference Between These and Control Average
3	1.009	.040	.931	.983	1.011	1.058	.976	.956	1.004
			.955	.950	1.054	.968	1.027	—.043	—.005
			.943	.970	1.032	1.008	1.001		
9	1.042	.041	1.028	1.032	1.012	1.034	1.042	1.004	1.044
			1.043	.912	1.014	1.096	1.002	—.038	+.002
			1.036	.972	1.013	1.066	1.022		
14	1.005	.064	1.068	.972	.959	.936	1.043	1.065	1.049
			1.055	1.168	.996	.987	1.230	+.060	+.044
			1.061	1.070	.978	.961	1.137		
Av.	1.019	.048	1.013	1.004	1.008	1.012	1.053	1.008	1.033
								—.011	+.014

TABLE XXXIV

THREE-HOLE TEST. SQUAD IV., EXPERIMENT *A*

Ratio of records after dose to records before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	Caffein 3 Gr.	4 Gr.	6 Gr.	Average 1 and 2 Gr. Also Difference Between These and Control Average	Average 4 and 6 Gr. Also Difference Between These and Control Average
5	.976	.089	.886	1.085	1.040	1.011	1.067	.999	1.058
			1.080	.945	1.027	1.084	1.072	+.023	+.082
			.983	1.015	1.033	1.047	1.069		
6	1.009	.029	.935	.985	1.018	1.087	1.045	.965	1.035
			1.008	.933	1.022	.942	1.065	—.034	+.026
			.971	.959	1.020	1.015	1.055		
10	.978	.028	1.001	.995	.968	1.058	1.015	.975	1.035
			.957	.956	1.041	1.035	1.043	—.003	+.057
			.979	.971	1.004	1.041	1.029		
11	.999	.093	.908	.895	1.078	.984	.884	.893	.952
			.925	.848	.874	.907	1.035	—.106	—.047
			.916	.871	.976	.945	.959		
16	.970	.050	.935	1.117	.914	.977	1.100	.961	.992
			.900	.896	.816	.932	.960	—.009	+.022
			.917	1.006	.865	.954	1.030		
Av.	.987	.057	.953	.964	.979	1.000	1.028	.958	1.014
								—.025	+.027

5:30 trial in another. In addition to the ratios and their M.V.'s the difference between the final averages for control and for caffein days is given, the 1 and 2 gr., and the 4 and 6 gr. doses being here averaged together. The results from both these tables confirm the statements already made concerning this squad—the small doses result in stimulation while the large doses are followed by retardation. The effect on this squad is, however, slight, and the three individuals do not all closely follow the rule drawn from the squad average. The small amount of both stimulation and retardation found here is apparently due to the time of day at which the dose was taken (10:30 A.M., a point of maximum efficiency).

In the case of Squad III. the separate records for each of the caffein days are given, as well as the averages. Subject 3 is always stimulated by the 1 and 2 gr. amounts. For larger amounts the majority of the days show retardation, only two days showing stimulation. Averaging the 1 and 2 gr. gives 4.3 per cent. stimulation, while the average of the 3, 4 and 6 gr. amounts gives retardation. The same is true of subject 9, while subject 14 is retarded by both small and large doses. The average for the squad gives 1.1 per cent. stimulation for small and 1.4 per cent. retardation for large doses. These amounts are somewhat larger than those of Squad II.

With Squad IV., the result is most striking and the magnitude of the effect greatest. The average of the five subjects gives 2.5 per cent. stimulation for small doses and 2.7 per cent. retardation for large. All the subjects follow much the same rule, and it is apparent that the magnitude of the caffein effect varies with body weight. Subjects 5 (105 lbs.) and 11 (110 lbs.) are affected by as much as 8 and 10 per cent. Subjects 6 (125 lbs.) and 10 (157 lbs.) run only as high as 3 to 6 per cent., while the heaviest subject, No. 16 (174 lbs.) has a maximum average of only about 2 per cent.

Thus whether the corresponding records of control days, or the average performance on a given day before the dose is taken, be adopted as the standard of comparison, the same result is indicated. In all respects these results resemble closely those yielded by the typewriting test, which is reported in another chapter. In the typewriting test the speed of performance is quickened by small doses of caffein (1 to 3 gr.) and retarded by larger amounts (4 to 6 gr.).

SUMMARY

The following statements are borne out by the data. The effect of small amounts of caffein on the coordination test is stimulation, while that of larger amounts is retardation. There is some evidence

that the retardation produced by the largest amount (6 gr.) is subsequent to a slight initial stimulation. The caffein effect is slight in the case of the squad taking the dose in the A.M. It is somewhat greater in the case of the squad taking the dose at the lunch hour, and is greatest of all when the dose is taken in the P.M. without food substance. Further, the magnitude of the caffein effect varies inversely with the body weight of the individual tested.

CHAPTER VII

Influence of Caffein on Speed and Quality of Performance in Typewriting[1]

The greater part of the previous work on the influence of drugs has been directed toward the study of relatively simple mental and motor processes such as reaction times, free and controlled associations, reading, adding, hitting at dots, and especially the production of ergograms. In the present experiments, in addition to the investigation of the series of similarly simple processes reported in the preceding chapters, an attempt was made to measure the influence of caffein alkaloid on a more complicated process, that of performance in typewriting.

Subject No. 2, a woman of 38 years, already fairly proficient in typewriting by the touch method, did not take part in the tests through which the previously described squads were put. Instead she made systematic records of her skill in typewriting throughout the four weeks. Ruskin's "Sesame and Lilies" was chosen as the material to be copied, since it was fairly uniform in character and interest throughout, and was unfamiliar to the subject. The pages of the edition used contained 27 lines, the lines containing on the average 35 characters (letters and punctuation marks). The pages were placed in a random order on an improvised holder, directly over the machine and on a level with the writer's eyes. Care was taken to keep the lighting conditions as constant as possible and the amount of disturbance through the day at a minimum. The subject corrected all mistakes noticed at the time they were made, and record was made (1) of the time taken to write the standard amount, (2) the number of corrected errors and (3) the number of errors passing undetected. The time record was kept by the subject herself, but the errors were counted after the close of the experiment, by a second person and checked up by a third.

During the first 27 days of the experiment the standard amount was 3 pages. This amount was written 7 times daily, the hours being at 8:00, 9:00, 10:00, 11:00, 2:00, 3:10 and 5:30, in order to distribute the trials as much as possible over the entire day. During the first week only sugar doses were taken, the object being, as in the case of

[1] This chapter is reprinted from the *Psychological Review*, January, 1912.

the squads already described, to reach a practise level and to secure perfect adaptation to the conditions of the experiment before the caffein was administered. After the first week caffein doses were given, in capsule form, on alternate days, the subject being in no case able to distinguish between the caffein days and the control days. This arrangement gave two days for each of the 1, 2, 3, 4 and 6 grain doses employed. The doses were given in increasing amounts, and in all cases just after the first trial for the day had been made, this time being about 8:30 A.M. When caffein is taken in capsule form its effect does not begin until about one hour after taking. Consequently, besides comparing the absolute amount of work done on caffein days with the amount done on control days, the first two trials of each day may be used as a normal performance for that day and the ratio of the five later trials to this normal computed for both kinds of days.

On the remaining 3 days (the intensive experiment) the subject came to the laboratory daily at 10:00 A.M. and wrote 2 pages each half hour (excepting short intermissions for lunch and dinner) until 9:15 P.M. thus making 19 trials each day. On the first of these three days 3 grains of caffein were taken at 3:15 P.M., just before beginning the 10th trial. On the second day a control capsule was taken at the same hour and on the third day a 6 grain dose of caffein. During these days there was absolutely no evidence of practise effect, the subject having reached her level some time before the intensive experiment began. It should be stated that when the book had been copied through once its pages were shuffled again and re-written in random order.

Rivers has made some use of the typewriting test in his work on the effects of caffein and alcohol by inserting periods of writing between the successive performances on the ergograph. In the case of alcohol neither the speed nor the accuracy of the writing seemed to be affected. "There is certainly no indication of any favorable action of the alcohol" (p. 96). "The errors in typewriting fall into two classes—those which escape notice and those which are noticed and corrected. . . . It will be seen that the latter are not very numerous, and so constant in number that they give not the slightest indication of an alcohol-effect. The uncorrected errors occur more frequently, and show an unmistakable tendency to increase with the rapidity of the work, being most numerous in the second interval of the fifth day, when the amount of work reached its maximum. When this increase with rapidity of work is taken into account, there is no definite indication of any alcohol-effect" (pp. 97–8).

There is however a striking discrepancy between these statements

of Rivers and the table (p. 96) on which he bases them. The table referred to is given complete below and the discrepancy pointed out because of its bearing on certain results of the present experiment.

TABLE III[1]

	May 17 No dose	May 19 Control	May 21 40 c.c.	May 23 20 c.c.	May 25 No dose	May 27 20 c.c.	May 29 Control	May 31 Control
1st interval								
Quantity of work	832	824	841	884	883	847	871	902
Corrected errors	47	56	86	80	89	74	86	94
Uncorrected errors	26	30	38	26	39	27	21	31
2d interval								
Quantity of work	797	842	805	884	956	897	885	904
Corrected errors	86	71	80	92	140	99	107	127
Uncorrected errors	45	46	31	26	42	36	44	19

Contrary to the statements quoted in the preceding paragraph, the *corrected* errors are without exception much more numerous than the *uncorrected*. This, it will later be seen, was also the case in the present experiment. The absolute numerical proportion between the two types of errors is of course immaterial and even their relative numbers would depend chiefly on the attitude of the subject toward the question of corrections.

In River's experiments with caffein .3 gram of caffein citrate, equivalent in strength to about 2.5–3 grains of the alkaloid, was taken morning and evening for 6 days, and on mornings only for another 6 days adequate control doses being employed (gentian and citric acid). The dose was taken 10 minutes before the work began. With respect to speed, this experiment showed "the distinct superiority of the caffein days" (p. 45). The number of mistakes was also determined and "here it came out quite definitely that the drug was without influence."

Of the three most available methods of presenting the results of the present experiment only two show clear results. One might on the one hand map out the efficiency curve for the various days, thus indicating, on each day, the course of the performance before and after taking the dose. But diurnal variations arising from other causes obscure the relatively slight influence of the drug from this point of view. A more satisfactory way is to compare the total amount of work done on the caffein days, after the dose has been taken with the similar records afforded by the control days, thus indicating the general capacity for work rather than the diurnal course of efficiency. Or instead of the total amount of work done we may use to advantage the ratio of this amount to the normal work of the

[1] Rivers, "The Influence of Alcohol and Other Drugs on Fatigue," p. 96.

respective days, the normal consisting of the work done before the dose was taken.

From the point of view of speed of performance both of these latter methods show clearly that doses of 1–3 grains of caffein alkaloid are stimulating in their effect while larger doses (4–6 grains) produce retardation. Fig. 12 records the total time taken for the 6 trials after the capsule was taken, for each of the 19 days of the first series of tests, beginning with the last day before the caffein doses commenced. The broken line follows the records for the control days and the solid line that for the caffein days, the time being recorded in minutes. The 1 and 2 gr. doses show indication of decided stimula-

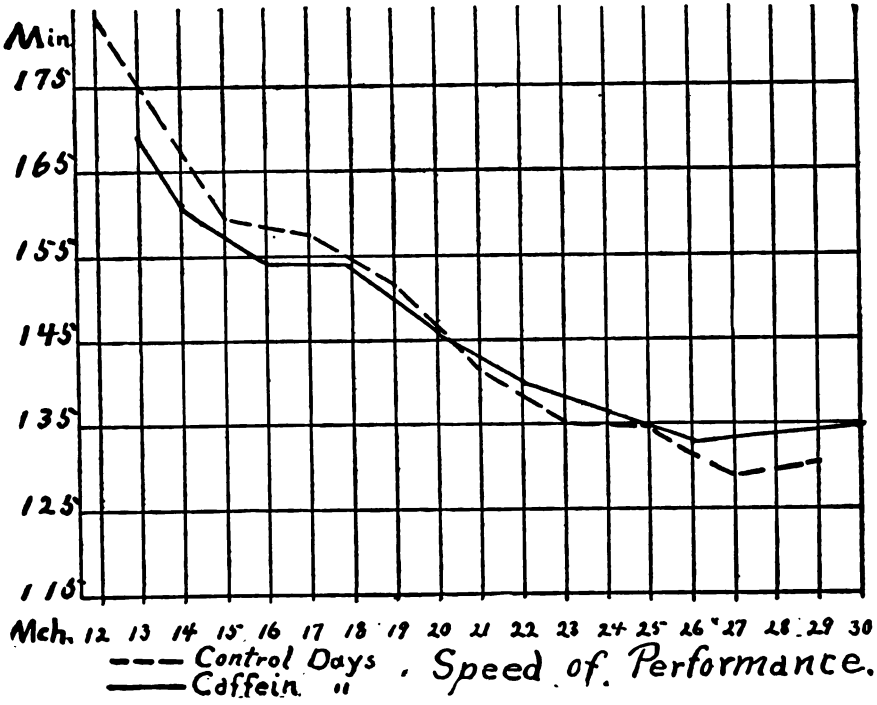


FIG. 12. SPEED IN TYPEWRITING. Showing the total time required for the six trials after the dose, on each day. Broken line represents control days and solid line caffein days.

tion, but at the 3 gr. dose the curves cross, the larger doses of caffein yielding longer times than those of the control days. Presented in this manner, however, the stimulation is somewhat obscured by the practise effect shown by the curves as a whole.

In order to eliminate this factor of practise to a greater degree

and to allow for daily variations of an irrelevant sort, I have computed the ratio of the average performance after the dose to the normal performance of each day, this normal being secured by averaging the first two morning trials. These ratios give the curves of Fig. 13 in which again the broken line represents the ratios for the control days and the solid line those for the caffein days. The effect suggested by the curves of Fig. 12 is here very clearly repeated, except that the retardation does not appear until the 4 grain dose is reached. The curve for the control days is practically a horizontal

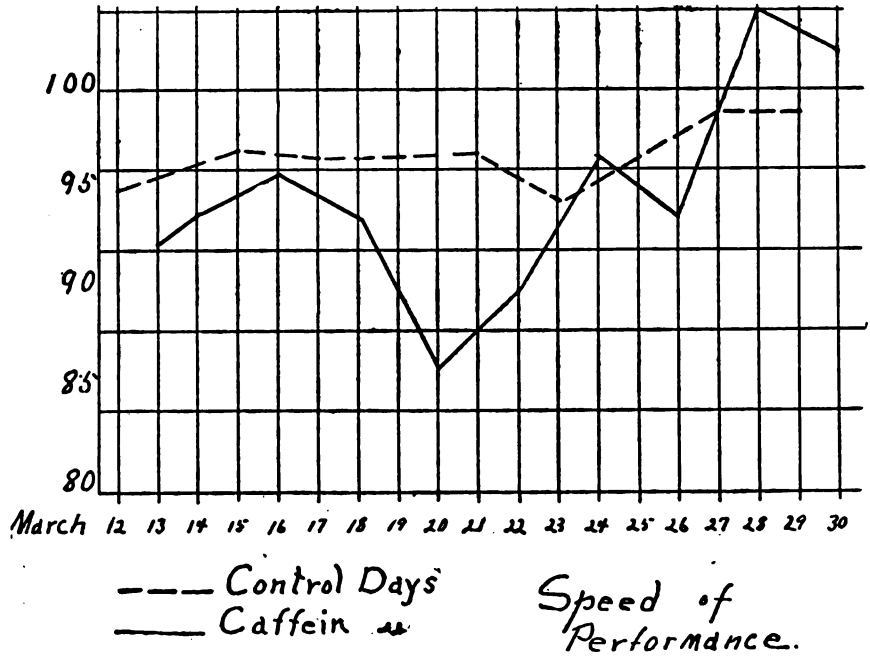


FIG. 13. SPEED IN TYPEWRITING. Showing the ratio of the average performance after the dose to the normal performance before the dose on the corresponding day. Broken line represents control days and solid line caffein days.

line, showing uniform maintenance of the normal throughout the control days. But the solid line shows improvement over the daily normal after doses of 1–3 grains and retardation below the daily normal after larger doses.

Table XXXV. shows the final averages of the daily totals for the last five trials of all the days. The control days and all the caffein days, regardless of the size of the dose, are averaged, and the time, the number of corrected errors, the number of uncorrected errors and the total errors recorded in separate columns.

TABLE XXXV

Averages for	Time	Errors Corrected	M.V.	Errors Uncorrected	M.V.	Total Errors
Control days	146.7	208	7	73	14	281
Caffein days	145.7	201	11	66	13	267

The average times balance, on account of the compensating effects of the small and large doses. The averages for both kinds of errors are smaller on caffein days than on control days, but the mean variations are fairly large and the difference is quite within the range of the probable error. Nevertheless the fact that it is a genuine difference is apparently borne out by the results of the intensive experiment which follow. But the difference is so small that curves corresponding to those for the times fail to show anything clearly.

Table XXXVI. gives the results of the three-day intensive experiment, in which 19 trials were made, the dose being taken at the time of the 10th or median trial. The table gives the totals for the 9 trials before the dose, comparing these with the totals for the 9 trials following it.

TABLE XXXVI

INTENSIVE EXPERIMENT

		First Nine Trials	Last Nine Trials	Difference	Per Cent. Loss or Gain
	Control	128.6	132.1	+ 3.5	+.027
Time	3 grains	130.1	129.5	— .6	—.005
	6 grains	131.5	131.3	— .2	—.002
Corrected	Control	189	176	— 13	—.068
errors	3 grains	216	156	— 60	—.277
	6 grains	273	170	—103	—.377
Uncorrected	Control	35	49	+ 14	+.400
errors	3 grains	42	35	— 7	—.167
	6 grains	59	34	— 25	—.423
Total	Control	224	225	+ 1	+.005
errors	3 grains	258	191	— 67	—.259
	6 grains	332	204	—128	—.385

These figures confirm the previously drawn conclusions. With respect to speed of performance the slight fatigue present on control days gives place to very slight stimulation on caffein days. The actual difference in time is, however, so slight as to be, in this case, scarcely worth mentioning. And this is what we should expect when the 3 and 6 grain doses are taken. But the difference in the number of errors of both kinds is very great. On control day the corrected errors are slightly less after the dose than before it (— 6.8 percent.). But after the 3 grain dose they decrease much more decidedly

(— 27.7) and after the 6 grains still more so (— 37.7 per cent.). The uncorrected errors are greater for the last 9 trials on control day, clearly less after 3 grains of caffein (— 16.7) and strikingly less after 6 grains (— 42.3 per cent.). Compared with the first 9 trials the total errors for the last 9 trials are greater for the control day, less for the 3 grain dose, and still less for the maximum dose of caffein. Contrasted with Rivers' result for alcohol, the time and the errors grow less, simultaneously, and the superiority of the work, from the point of view of errors, which did not seem to be present in Rivers' tests of caffein, is clearly shown. But this superiority is seen only when the general capacity for work, over a considerable period of time, is examined. When the results are platted so as to show the course of the performance throughout the day, the curves are obscure.

Summary

The speed of performance in typewriting is quickened by small doses of caffein alkaloid (1–3 grains) and retarded by larger doses (4–6 grains). The quality of the performance, as measured by the number of errors, both corrected and uncorrected is superior, for the whole range of caffein doses (1–6 grains), to the quality yielded by the control days. Both types of errors seem to be influenced to about the same degree. The increase in speed is not gained at the expense of additional errors, but increased speed and decreased number of errors are simultaneously present.

CHAPTER VIII

The Influence of Caffein on the Color-naming Test

When the investigation began, a few preliminary trials seemed to indicate that ordinary daylight would afford conditions which would be so constant as to produce no great variability in the color-naming test as the result of fluctuating illumination. But the work had not progressed far before it was found that the diurnal variations in sunlight were so great as to constitute a disturbing factor in the records. On most days there was insufficient daylight at the 5:30 test for the colors to be promptly distinguished, while the introduction of such artificial light as was then available changed appreciably the color tone of the bits of paper. Rather than disturb the experiment when it was well under way and trusting to the 3:10 trial for indications of the character of the caffein influence, if such were present, it was decided to omit the color-naming test at the 5:30 period in Experiment *A*, thus giving only one trial after the dose. The result was that nothing came of this test in Experiment *A*. Such influence as was present was too tardy to be revealed so soon after the dose, hence the 3:10 records differ in no respect from those of the three trials before the dose. In Experiments *B* and *C* a gas mantle was secured which gave a fairly pure white light and the test was conducted in this artificial illumination at all trials, including 5:30.

Experiment *C*

Experiment *C* will serve to give an introductory view of the character of the caffein influence on this fairly simple association process. Table XXVII. gives the records (Av. and M.V.) for the one squad of 12 subjects used here, for each of the five trials on the various types of days. Further, since the doses were taken before the 3:10 and 5:30 trials (15 minutes before the trials began) the 7:45, 10:00 and 12:00 records have been averaged to constitute a normal record for each type of day and the two trials (3:10 and 5:30) following the dose, when averaged, give the indication of caffein influence. In a final column is given the ratio of this afternoon average to the normal performance in each case.

The blank days (no dose whatever) show fatigue in the latter part of the day, the afternoon's work averaging 105.4 per cent. of

TABLE XXXVII

COLOR-NAMING. EXPERIMENT C

Trial		7:45	10:00	12:00	3:10	5.30	Av. 1st 3	Av. 4 and 5	v. 4 and 5 Per Cent. of Av. 1, 2 and 3
Blank days,	Av.	54.8	53.4	58.4	58.9	58.0	55.5	58.5	105.4
24 cases	M.V.	9.5	7.0	8.6	7.2	7.0	8.4	7.1	
Syrup days,	Av.	56.0	55.8	60.0	55.2	57.3	57.3	56.2	98.1
24 cases	M.V.	8.8	6.0	7.4	9.4	9.1	7.4	9.3	
Syrup and 1.2 gr.	Av.	53.8	57.2	59.2	53.0	55.9	56.8	54.5	95.9
caffein, 12 cases	M.V.	9.4	7.1	8.3	6.2	8.5	8.3	7.3	
Syrup and 3.6 gr.	Av.	55.4	57.3	61.2	54.5	55.5	58.0	55.0	94.8
caffein, 12 cases	M.V.	9.1	8.6	8.8	9.3	9.7	8.5	9.5	
Syrup and 6 gr.	Av.	59.5	56.4	60.4	56.4	58.1	58.8	57.3	97.4
caffein, 12 cases	M.V.	13.4	9.5	9.2	9.5	11.4	10.7	10.5	
Caffein Av.,	Av.	56.2	56.9	60.9	54.6	56.5	57.9	55.6	96.0
36 cases	M.V.	10.6	8.4	8.8	8.3	9.9	9.3	9.1	

the normal. On the plain syrup days the 12:00 o'clock period shows the same tendency beginning, but after the syrup doses (taken with carbonated water) the record falls instead, the work after the dose averaging 98.1 per cent. of the normal, an absolute stimulation of 2 per cent., or a relative stimulation, as compared with the blank days, of 7.5 per cent. After syrup containing 1.2 gr. of caffein (also taken with carbonated water) the initial tendency to fatigue is again transformed into stimulation, this time resulting in a superiority of 9.5 per cent. over the blank days. After 3.6 gr. of caffein this relative stimulation rises to 10.6 per cent., and after 6 gr. there is an average superiority over the blank days of 8.0 per cent. The average of all the caffein doses shows clearly the same initial tendency to fatigue that is present on days with no doses, and also, in sharp contrast with these latter, the considerable stimulation following the dose (average absolute 4.0 per cent., average relative 9.4 per cent.).

The whole amount of this stimulation can not however be attributed to the caffein, since the plain syrup doses yielded an absolute stimulation of 2 per cent. The effect here is no doubt simply a case of sensory and psychic stimulation, produced partly by the excitement and interest of taking a drink with unknown contents, and partly by the sensory effects of the carbonated water, the act of swallowing, etc. To get the true caffein effect, then, this plain syrup effect must be allowed for, but the double control afforded by the blank days on the one hand and by the plain syrup days on the other, renders highly reliable the conclusion concerning the character of the caffein effect.

Since the net caffein stimulation is in this experiment present at

the 3:10 period the effect of the drug would seem to begin in about half an hour after taking the drink. Obviously this result is not comparable with that secured when the caffein is administered in capsules. Taken with the syrup the substance is already in solution and the reaction would be expected to follow more quickly than in the case of the capsule doses.

EXPERIMENT *B*

For further information as to the reaction time and for data concerning the duration and the after effect of the stimulation the results of the intensive experiment, in which the capsules were chiefly used, must be examined. Curves 14 to 17 give the average records for the various squads at each of the successive trials, on each of the three days, the solid line representing March 3, the broken line March 4 and the dotted line March 5.

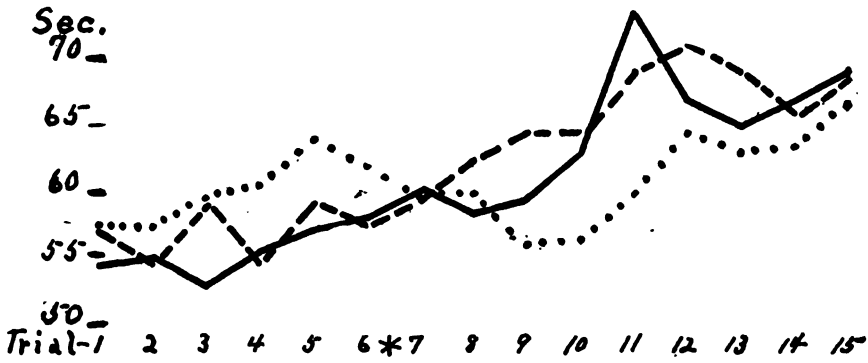


FIG. 14. COLOR-NAMING TEST. Experiment *B*. Squad I. (Control.)

Squad I. ran for the first two days on sugar doses only. The curves for these two days indicate in a very striking way the normal tendency to fatigue which this color-naming test shows. On the last day this squad received 3 gr. capsules of caffein after the 6th trial. At the 2d subsequent test (90 minutes later) the squad responds with a stimulation that is as pronounced as was the fatigue effect of the preceding days. After this strong stimulation the curve begins to rise again toward the normal fatigue level. But this level is never reached, for after the 12th trial a second capsule, containing 2 gr. of caffein was given, whereupon the curve drops again. A second stimulation thus follows upon the first, just as the curve is about to reach the fatigue level. Three hours after the first caffein influence begins to show itself there is still evidence of the primary stimulation produced by the 3 grain dose.

Squad II. took syrup with caffein (1.2 gr.) on March 3 and 5, and a sugar capsule on March 4. This last day shows the normal fatigue curve present also in Squad I. and in Experiment *C*. But 2–2½ hours after the caffein drink on March 3 the curve drops to a

FIG. 15. COLOR-NAMING TEST. Experiment *B*. Squad II. (Solution.)

level lower than that of the performance before the dose. Evidence of this stimulation is still present at the close of the day, a persistence time of nearly 4 hours. On the following morning there is no evidence of relapse, the three curves starting at approximately the same level, with a slight superiority in favor of the last two days.[1]

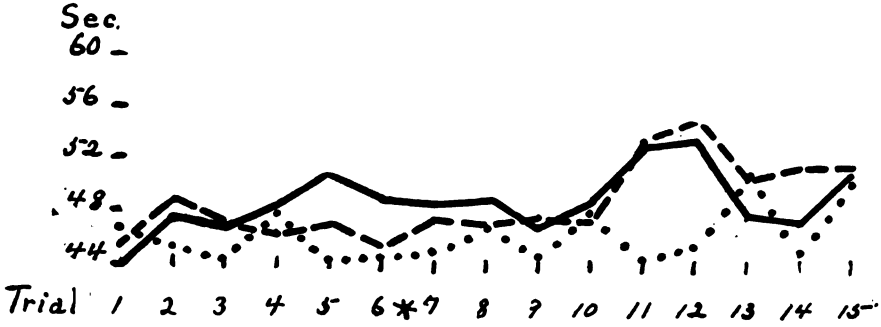


FIG. 16. COLOR-NAMING TEST. Experiment *B*. Squad III. (3 gr.)

The second dose of caffein for this squad (March 5) does not show the same amount of stimulation that is present after the first dose. The general level of the curve drops but slightly, although the tendency is clearly to follow the level of the previous caffein day rather than that of the control day.

[1] This tendency of the curves to drop to lower general levels on the successive days is present with Squads III. and IV. as well. If it be recalled that on these intensive days the 100 colors were named in the same order at each of the 45 trials it will not be at all surprising that this slight appearance of general practise or familiarity is present.

With Squads III. and IV. (doses of 3 and 6 gr. respectively on March 3, and sugar doses on the remaining days) the results are not so apparent as those of Squads I. and II. The net result of the caffein on Squad III. seems to have been to relieve fatigue at the last tests of the day. This evidence is reenforced by the fact that the curve for the following day, although it begins on a lower level (probably as a result of the general practise pointed out above) finishes somewhat higher than that of the first day. Squad IV. behaves in much the same way as Squad III. The curve for the caffein day, beginning considerable higher up than that of the day after, finishes on about the same level. Fatigue on the third day is

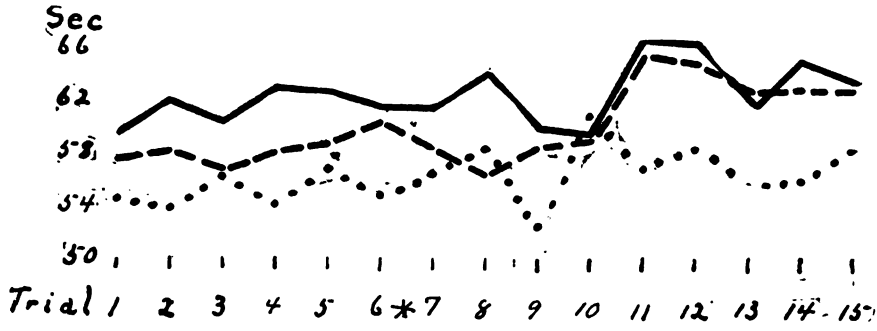


FIG 17. COLOR-NAMING TEST. Experiment *B*. Squad IV. (6 gr.)

slight. Perhaps the only safe inference to be drawn from the records of these two squads is the negative one, that caffein (in 3 and 6 gr. amounts) has at least no depressing effect on this test. The evidence from Squads I. and II. and from Experiment *C* is quite sufficient to demonstrate that when any effect is present it is stimulation.

SUMMARY

There is clear indication of stimulation in the color-naming test for the whole range of doses employed. But in all cases this stimulation is more apparent after the smaller doses than after the larger. The effect begins in about 2 to 2.5 hours after the capsule has been taken and is still present 3 to 4 hours later. There is no evidence of any after effect on the following day. Of incidental interest is the considerable retardation produced in this test by the evening meal. (See intensive curves.)

CHAPTER IX

The Influence of Caffein on the Opposites Test

In the opposites test, as in the color-naming test which precedes and in the calculation test which follows, there were no errors allowed, so that the only record to be made was the time of performance. In all cases the amount and quality of performance was constant. In the following curves of Subject 10 for Experiment *A*, a typical caffein effect is to be seen. The first two curves represent records made at the 12:00 period, before the dose was taken. At 5:30, four and a half hours after the dose, which was taken at the lunch hour, the second pair of curves results. The broken line represents days on which the dose was sugar, while the solid line represents the caffein days, the first two records being 1 gr., the next two 2 gr., and the following pairs 3, 4 and 6 grains. This subject is seen to be stimulated by the smaller doses of caffein, the solid line running lower at the 5:30 period than does the curve for control days. In the case of the larger doses there is no clear evidence of stimulation on the part of this subject. These individual curves are given only as suggestive of the character of the caffein influence for a more complete knowledge of which the results from the squad averages are given in the following.

Experiment *A*

Tables XXXVIII.–XLV. give the results of Experiment *A* for all four squads. The data here are treated in the same way as were those in the case of the tapping test, the actual records on caffein days being compared with calculated records for the same days. These calculated records are secured by averaging the records of the preceding and the following control day at the corresponding trial. The records for the respective doses are then averaged, and the difference between actual and calculated records computed. Cases in which the control records were longer are marked +, and cases in which the control records are quicker are marked —. After the dose has been taken, on a given day, the + differences will indicate stimulation, while the — differences will indicate retardation. But at the trials before the dose, the reverse will be the case, since the morning records of control days follow upon the caffein doses of the preceding days.

TABLE XXXVIII

OPPOSITES. SQUAD I., EXPERIMENT *A*

	February																		
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
7:45	56.0	50.5	51.1	49.9	46.4	45.2	41.6	42.1	44.7	42.2	40.7	42.5	45.3	40.9	36.6	41.6	37.6	36.4	37.8
10:00	54.9	50.9	47.9	49.9	46.9	43.5	45.5	41.5	44.5	42.0	43.7	44.5	38.9	38.8	37.5	38.6	35.1	36.5	35.2
12:00	54.8	51.2	51.7	48.1	46.1	42.7	44.7	42.5	42.2	46.7	42.3	42.6	39.1	38.5	41.6	37.7	37.7	36.9	36.8
1:00	Dose, sugar doses only, daily.																		
3:10	54.9	54.0	54.7	56.3	47.5	48.8	49.7	46.9	43.5	47.3	43.3	45.7	41.9	42.9	38.1	40.9	42.3	43.1	34.8
5:30	58.2	50.9	51.5	55.1	56.3	50.3	46.3	47.3	43.1	46.2	46.7	41.4	42.3	45.5	39.6	40.9	44.4	40.4	36.3

TABLE XXXIX

OPPOSITES. SQUAD II., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	54.9	58.1	*53.0*	*48.2*	*49.1*	44.7	41.8	*42.1*	*42.7*	*43.2*	46.4	40.5	39.8	*35.7*	*38.4*	*35.8*	40.0	36.8	33.6	*37.3*	31.8
10:00	52.4	54.9	*51.1*	*45.2*	*44.9*	44.0	45.0	*41.1*	*39.6*	*39.7*	43.1	35.7	34.9	*36.7*	*39.2*	*36.1*	34.3	38.3	35.9	*35.0*	34.7
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*¼ gr.*	*¼ gr.*	*¼ gr.*	S	S	S	*6 gr.*	S
12:00	59.7	47.8	*52.7*	*45.7*	*48.7*	51.1	42.3	*40.2*	*47.1*	*43.1*	38.9	39.7	37.0	*36.7*	*36.3*	*43.5*	38.7	36.8	39.8	*34.8*	34.7
3:10	54.3	47.7	*49.6*	*50.5*	*47.0*	45.7	47.8	*40.5*	*41.8*	*44.0*	41.5	40.1	42.1	*38.7*	*34.0*	*36.9*	36.2	34.9	35.1	*33.7*	36.5
5:30	57.9	54.7	*50.8*	*43.5*	*53.4*	44.8	44.5	*43.7*	*40.7*	*43.9*	38.4	41.2	39.4	*35.4*	*35.8*	*38.1*	39.5	36.8	37.5	*36.7*	39.3

TABLE XL

OPPOSITES. SQUAD III., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	68.2	*60.5*	62.0	*53.7*	55.1	*50.7*	52.1	*43.7*	46.4	*44.2*	43.8	*41.8*	39.5	*41.7*	38.1	*35.4*	35.3	*37.4*	33.9	*37.3*	33.7
10:00	61.5	*59.8*	57.5	*56.1*	50.4	*46.9*	50.6	*46.1*	43.9	*43.7*	48.2	*45.2*	36.9	*37.7*	40.4	*36.5*	35.2	*36.9*	37.2	*37.9*	33.9
12:00	66.6	*58.1*	62.8	*53.1*	51.6	*51.7*	51.5	*46.5*	44.4	*47.3*	43.3	*41.6*	41.1	*40.3*	42.1	*39.0*	35.1	*36.6*	34.3	*36.9*	36.1
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	63.7	*56.7*	54.1	*58.1*	50.0	*50.3*	46.4	*44.7*	48.3	*45.7*	43.0	*40.4*	44.6	*45.0*	35.5	*33.5*	35.4	*37.7*	36.7	*32.1*	32.0
5:30	70.7	*62.4*	66.3	*54.5*	57.1	*50.9*	48.9	*47.3*	51.1	*45.5*	43.3	*41.4*	42.3	*41.4*	39.6	*38.7*	37.4	*39.5*	36.3	*35.4*	38.1

TABLE XLI

OPPOSITES. SQUAD IV., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	50.6	*48.4*	45.7	*44.8*	41.9	*40.6*	41.9	*42.0*	37.8	*39.1*	35.8	*36.4*	34.6	*35.9*	32.9	*35.9*	33.9	*33.8*	31.7	*34.1*	31.6
10:00	48.4	*46.1*	42.6	*47.2*	42.5	*41.4*	41.8	*39.2*	39.4	*40.6*	36.9	*36.5*	34.7	*35.1*	36.9	*33.3*	31.9	*34.1*	32.2	*31.7*	32.7
12:00	46.8	*48.7*	47.6	*46.8*	42.1	*42.4*	40.8	*38.6*	38.6	*40.0*	34.9	*38.0*	34.8	*39.9*	33.7	*34.4*	34.1	*38.2*	33.2	*32.2*	32.2
1:40	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	47.6	*44.9*	44.7	*43.5*	40.9	*41.9*	41.8	*38.9*	37.5	*36.6*	37.9	*39.4*	34.9	*35.6*	35.8	*34.1*	35.0	*32.9*	33.0	*34.1*	31.7
5:30	51.6	*46.8*	46.7	*43.5*	51.8	*43.4*	39.9	*38.6*	39.9	*39.2*	36.4	*35.2*	37.9	*37.6*	37.2	*34.4*	36.1	*33.0*	33.8	*32.8*	32.9

TABLE XLII

OPPOSITES. SQUAD I

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:20 Caf. Av.	Dif.
51.2	50.2	+ 1.0	49.4	50.4	— 1.0	51.1	49.7	+ 1.4	S	53.0	55.2	— 2.2	54.4	53.0	+ 1.4
43.6	43.7	— 0.1	45.6	42.5	+ 3.1	44.5	42.6	+ 1.9	S	47.6	47.9	— 0.3	48.0	48.8	— 0.8
42.9	42.4	+ 0.5	42.7	43.3	— 0.6	41.5	44.7	— 3.2	S	43.0	46.5	— 3.5	44.7	43.8	+ 0.9
40.9	40.9	0.0	38.2	38.8	— 0.6	40.8	38.5	+ 2.3	S	40.0	42.9	— 2.9	40.9	45.5	— 4.6

TABLE XLIII

OPPOSITES. SQUAD II., EXPERIMENT *A*

Doses at 10:30 A.M. on successive trios of days

Time	7:45	10:00	12:00	3:10	5:30	No. of Days
Control days	45.3	43.1	44.3	43.6	44.7	11
1 gr. caffein	50.1	47.1	49.0	49.0	49.2	3
2 gr. caffein	42.7	40.1	43.5	42.1	42.8	3
4 gr. caffein	36.6	37.3	38.8	36.5	36.4	3
6 gr. caffein	34.6	34.9	34.8	35.1	38.0	1
Caffein Av.	41.0	39.8	41.5	40.7	41.6	10

TABLE XLIV

OPPOSITES. SQUAD III., EXPERIMENT *A*

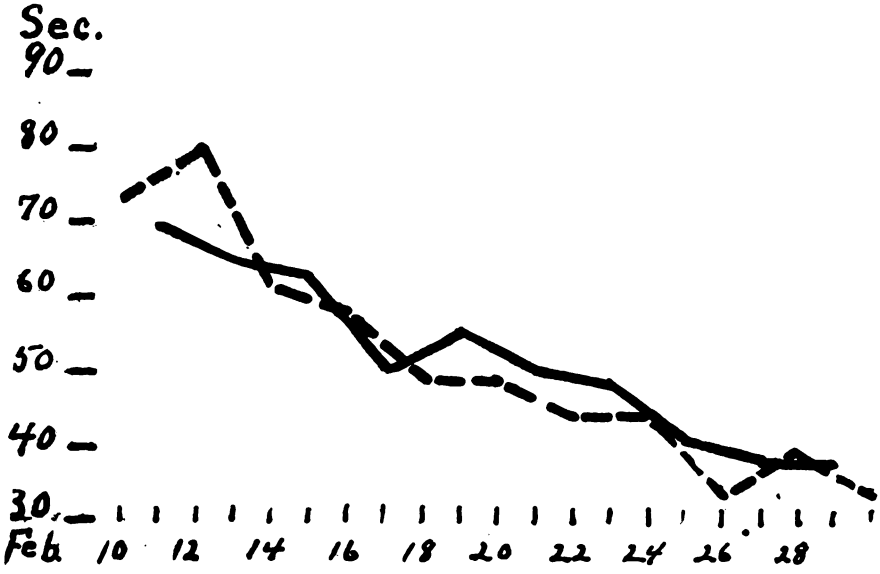
Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:30 Caf. Av.	Dif.
61.9	57.1	+ 4.8	56.8	57.9	— 1.1	61.0	55.6	+ 5.4	1 gr.	55.5	57.4	— 1.9	65.1	58.5	+ 6.6
51.5	47.2	+ 4.3	48.9	46.5	+ 2.4	49.8	49.1	+ 0.7	2 gr.	47.8	47.5	+ 0.3	51.5	49.1	+ 2.4
43.4	43.0	+ 0.4	44.4	44.5	— 0.1	43.1	44.5	— 1.4	3 gr.	44.8	43.1	+ 1.7	45.0	43.5	+ 1.5
37.8	38.6	— 0.8	38.3	37.1	+ 1.2	40.1	39.7	+ 0.4	4 gr.	37.8	39.3	— 1.5	39.8	40.1	— 0.3
34.2	37.4	— 3.2	35.9	37.4	— 1.5	35.0	36.8	— 1.8	6 gr.	35.3	34.9	+ 0.4	37.1	37.5	— 0.4

TABLE XLV

OPPOSITES. SQUAD IV., EXPERIMENT *A*

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:45 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:30 Caf. Av.	Dif.
46.0	46.6	— 0.6	44.1	46.7	— 2.6	46.1	47.8	— 1.7	1 gr.	44.5	44.2	+ 0.3	49.3	45.2	+ 4.1
40.9	41.3	— 0.4	41.4	40.3	+ 1.1	40.6	40.5	+ 0.1	2 gr.	40.6	40.4	+ 0.2	42.9	41.0	+ 1.9
36.0	37.8	— 1.8	37.0	38.6	— 1.6	35.9	39.0	— 3.1	3 gr.	37.1	38.0	— 0.9	37.7	37.2	+ 0.5
33.6	35.9	— 2.3	35.1	34.2	+ 0.9	34.1	37.2	— 3.1	4 gr.	35.4	34.9	+ 0.5	37.2	36.0	+ 1.2
32.3	34.0	— 1.7	32.3	32.9	— 0.6	33.2	35.2	— 2.0	6 gr.	33.2	33.5	— 0.3	34.2	32.9	+ 1.3

Turning now to an examination of these tables, the records for Squad I. show purely chance distribution of differences at all but the 3:10 period, the magnitudes being small and the signs as often + as —. But at 3:10 there is a tendency for the pseudo-caffein days to be somewhat slow, the differences between actual and calculated records being all negative, and averaging about 2.2 seconds, the time of performance ranging between 42 and 55 seconds. Since this squad had only sugar doses throughout the experiment, this apparent retardation on pseudo-caffein days must either be considered simply a chance affair, or else to point to some more general



OPPOSITES TEST. Subject IX. Experiment *A*. Taking caffein at 1:00 P.M., with lunch. Broken line represents control days and solid line caffein days.

FIG. 18. Test at 12:00 M. No difference between caffein and control days.

factor that happened to affect performance in this test at the period and on the days in question. In the latter case, the fact should be borne in mind in interpreting the results secured from the other squads.

Squad II. yielded the records found in Table XLIII. The calculation of actual and expected records is not carried out here, since the doses were alike on successive trios of days, as explained in Chapter II. Instead the averages for all periods on each type of day (control, 1 gr. caffein, 2, 4 and 6 gr. of caffein) are given. The dose was taken at 10:30 A.M. The records for control days show

slight inferiority at the morning trial (7:45) and the best record of the days at 10:00. After this time the record lies always between these two extremes, with no considerable variation. Comparing this with the caffein days, the drug seems in no way to have influenced the speed of performance. The caffein averages show the same relation to each other for all doses, with no clear indication of any difference in performance after the dose.

In the case of Squad III., the 3:10 records show no consistent differences between caffein and control days, but the superiority of control days, found in Squad I., is not present here. By the time of

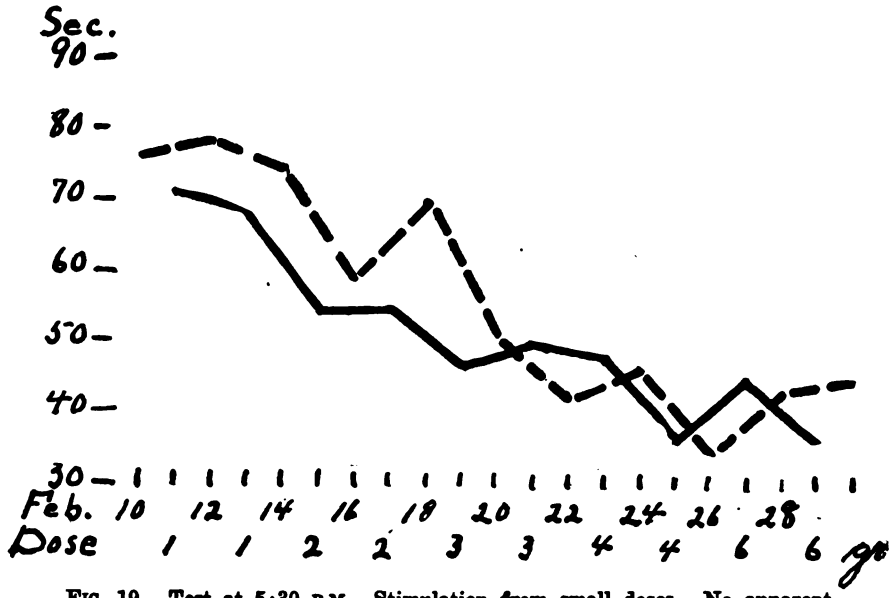


FIG. 19. Test at 5:30 P.M. Stimulation from small doses. No apparent effect from larger amounts.

the 5:30 test, caffein doses of 1–3 gr. yield considerable stimulation (6.6, 2.4 and 1.5 sec.). For larger doses the differences balance. The effect seems to decrease throughout with the magnitude of the dose. On the post-caffein mornings there appears to be retardation for the small doses of the day before, while the larger doses seem to result in stimulation at this late period. At 10:00 and 12:00 the differences are quite balanced. This squad took doses at the lunch hour.

With Squad IV., taking doses in mid-afternoon, the differences at the 3:10 period average less than .5 sec., and the signs balance, showing no effect unless the absence of the retardation found in the

case of the control squad be taken to be significant. At 5:30 there is stimulation for all doses, averaging 1.8 sec. or 4.5 per cent. The amount, as in the case of Squad III., is less for the large doses than for the smaller. On the following morning there is continued tendency to stimulation, especially marked at the 7:45 and 12:00 periods.

The effects of caffein on the opposites test in Experiment *A* are much more clearly shown if the standard of performance be taken

TABLE XLVI

OPPOSITES. SQUAD I., EXPERIMENT *A*

Showing the ratio between the records after the dose to the records before the dose. Comparing control days with pseudo-caffein days, for purposes of controlling data from the other squads

Subject	Control Av.	M.V.	Pseud. Caf. Av.	M.V.
1	1.041	.052	1.087	.048
4	1.007	.055	1.065	.038
7	.961	.044	1.066	.095
15	1.158	.090	1.133	.074
Average	1.041	.060	1.087	.063

TABLE XLVII

OPPOSITES. SQUAD III., EXPERIMENT *A*

Comparing the average record after the dose with the average record before the dose, on both control and caffein days

Subj.	Control Average	M.V.	Caffein 1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Caffein Average	Cont. Av. M.V.	—Caf. Av.
3	.986	.050	1.017	.991	.903	1.063	.994			
			.888	.986	.952	1.076	.929			
			.952	.988	.927	1.069	.961	.979	.050	—.007
9	1.019	.083	1.150	1.050	.943	.853	1.040			
			.785	1.020	1.015	.972	.865			
			.967	1.035	.979	.912	.952	.969	.087	—.050
14	1.018	.048	.968	1.046	1.003	1.111	1.106			
			1.021	.990	.972	.997	.923			
			.994	1.018	1.037	1.054	1.014	1.023	.054	+.005
Sqd. Av.	1.008	.060	.971	1.013	.981	1.011	.975	.990	.063	—.018

to be the average performance before the dose, instead of the corresponding record on control days. In the latter case the true influence is perhaps partially concealed by the large practise effect on this test. Using the performance before the dose as the standard, and computing the ratio of the performance after the dose to this standard, for all types of day, yields the figures given in Tables XLVI.–L. In the case of Squad II., where there were three trials

for each sized dose, the average and M.V.'s of these three trials are used, and the two earlier and the last trial of the afternoon are kept separate. In the case of Squads III. and IV., who had only two days for each dose, both records are given, as well as the averages. In the tables the difference between the average ratios on control days and the ratios on caffein days are also given. The control squad (Table XLVI.) yields the same appearance of retardation on pseudo-caffein days that was pointed out in the preceding discussion of that squad. If this effect be taken to indicate some common out-

TABLE XLVIII

OPPOSITES. SQUAD II., EXPERIMENT *A*

Showing the ratio of the 12:00 and 3:10 trials (Av.) to the average of the 8:00 and 10:00 trials. Dose at 10:30

Subj.	Control Av. and M.V.		Av. and M.V. 3 1 Gr. Days		Av. and M.V. 3 2 Gr. Days		Av. and M.V. 3 4 Gr. Days		1 6 Gr. Day	Caf. Av.	M.V.	Cont. Av. —Caf. Av.
8	1.026	.070	1.066	.056	1.005	.058	1.065	.073	.941	1.019	.060	— .007
12	1.004	.088	.959	.050	1.001	.043	.968	.033	.889	.954	.045	— .054
13	.993	.090	.995	.096	1.053	.120	1.049	.103	1.020	1.029	.106	+ .036
Av.	1.008	.083	1.006	.064	1.016	.072	1.027	.066	.950	.999	.064	— .009

TABLE XLIX

OPPOSITES. SQUAD II., EXPERIMENT *A*

Showing the ratio of the 5:30 trial to the average of the 8:00 and 10:00 trials. 7 hrs. after the dose

Subj.	Control Av. and M.V.		Av. and M.V. 3 1 Gr. Days		Av. and M.V. 3 2 Gr. Days		Av. and M.V. 3 4 Gr. Days		1 6 Gr. Day	Caf. Av.	M.V.	Cont. Av Caf. Av.
8	1.050	.063	1.118	.043	.979	.026	.999	.110	1.023	1.029	.059	— .021
12	1.024	.110	1.049	.096	1.091	.130	.967	.073	1.019	1.019	.099	— .005
13	1.023	.070	.944	.060	1.149	.080	.995	.076	.997	1.021	.072	— .002
Av.	1.032	.081	1.037	.066	1.073	.078	.987	.086	1.013	1.023	.076	— .009

side factor influencing the records on these days, the amount of stimulation indicated in the tables for the caffein squads is much less than what was really present, by some 8 per cent.

Consistently with the results indicated by other tests, the squad taking the dose in the A.M. (Squad II., Tables XLVIII. and XLIX.) shows the least influence. The stimulation present with this squad comes from the larger doses. The average amount for the squad is .9 per cent. at both the earlier and later trials of the afternoon.

Squad III. (dose with lunch) yields an average stimulation of twice this amount (1.8 per cent.). Only the heaviest of the three subjects, No. 14 (193 lbs.) fails to be stimulated, and it is this individual whose records bring the squad average down so low as it is.

As would be expected from the results of other tests, Squad IV. shows the caffein influence most clearly and to the greatest degree. The individual averages show stimulation without exception, the amounts, on the basis of the average for all doses, ranging from 2 to 12.5 per cent. The squad average for all doses is a stimulation of almost 6 per cent. Four of the five subjects get the greatest stimulation from the small doses. This is perhaps to be at least partly

TABLE L

OPPOSITES. SQUAD IV., EXPERIMENT *A*

Showing ratio of trials after dose to trials before dose. Dose at 1:45 P.M. Average of 3:10 and 5:30 records compared with average of 8:00, 10:00 and 12:00 records

Subj.	Control Average	M.V.	Caffein 1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Caffein Average	M.V.	Cont. Av. —Caf. Av.
5	1.079	.060	.990	1.023	.860	.914	.890			
			.963	.890	1.033	.972	1.007			
			.976	.956	.946	.943	.948	.954	.052	—.125
6	1.048	.041	.960	1.000	1.038	1.048	.948			
			.885	1.125	.973	.932	.963			
			.922	1.062	1.005	.990	.960	.987	.050	—.061
10	1.033	.041	.978	1.120	.935	1.067	1.004			
			.996	1.004	.917	1.075	1.048			
			.987	1.062	.926	1.071	1.026	1.014	.051	—.019
11	1.011	.047	.938	.993	1.023	.959	.893			
			.928	.850	1.038	.945	1.047			
			.933	.921	1.030	.951	.970	.961	.053	—.050
16	1.018	.043	.940	.933	.915	.953	.961			
			.992	1.053	1.151	.994	1.000			
			.961	.993	1.033	.973	.980	.988	.048	—.030
Sqd. Av.	1.038	.046	.955	.998	.988	.985	.976	.960	.050	—.058

explained by the fact that the larger doses were given at a later point on the practise curve, when the individual was approaching more nearly to his physiological limit. In this case a smaller measurable amount might well indicate a greater caffein influence. The three individuals showing the greatest stimulation are subjects 5, 11 and 6, whose weights are 105, 110 and 125 lbs. respectively. Subjects 10 and 16, who get less stimulation from the same doses weigh 157 and 174 lbs. respectively. The dependence of the magnitude of the caffein influence on body weight is thus once more demonstrated. Comparing the three caffein squads, the caffein influence

is seen to be greatest when the dose is taken in the P.M. without food substance; it is less when the dose is taken with the mid-day meal, and still less when taken in the middle of the forenoon.

EXPERIMENT *B*

The results of Experiment *B*, the three intensive days, are given in curves 20–23. Here, as in the case of the other tests, the solid line represents March 3, the broken line March 4 and the dotted line March 5. Squad I. (control), Curve 20, shows clear indication of caffein stimulation. The first two days (sugar doses only) yield fatigue curves, the performance decreasing in speed from 35 seconds in the first two trials to an average of 45 seconds at the last two trials, a fatigue of 28 per cent. of the original time of performance. But on March 5, after the 3 gr. capsule of caffein after the 6th trial, the curve sweeps downward instead of upward,

FIG. 20. OPPOSITES TEST. Experiment *B*. Squad I. (Control.)

being, at the 9th trial, 2.5 hours after the dose, several seconds lower than the original performance at the morning trials. This effect remains during three trials (2.5 hours). After this point the curve approaches the normal fatigue level, but is brought down again by the additional 2 gr. dose late in the evening. Before the dose the curves pursue quite the same level, but after the dose the trials for the rest of the day average 39.4 seconds on the first control day and 42.0 seconds on the second, as compared with 35.8 seconds on the caffein day.

In the curves for Squad II., all three days start out on about the same general level. On March 3 the curve then starts upward, as though the normal fatigue already seen in Squad I. were taking

place. But about 1 hour after the glass of syrup, carbonated water and 1.2 gr. caffein, taken after the 6th trial, the curve sweeps downward and remains low for the rest of the day, the second and fourth records from the end being the best of the whole day. On the following day (sugar dose after 6th trial) the fatigue effect is clearly present, the gradual rise being from a level of 30 seconds to one of

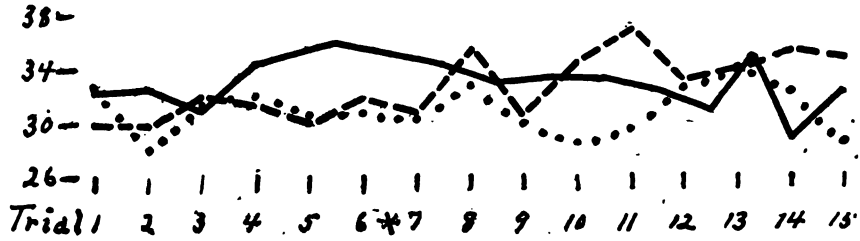


FIG. 21. OPPOSITES TEST. Experiment *B*. Squad II. (Solution.)

over 35 seconds. On the third day (caffein in syrup again after 6th trial) the tendency to fatigue is once more counterbalanced by an absolute stimulation beginning about 2 hours after the drink was taken.

The March 3d curve for Squad III. runs on a uniform level of 32 seconds until just before the dose, when the level drops to 30 seconds. After the 3 gr. caffein capsule between the 6th and 7th trials,

FIG. 22. OPPOSITES TEST. Experiment *B*. Squad III. (3 gr.)

the curve rises slowly until it again reaches the 32 second level, where it remains for the rest of the day. No evidence of fatigue is present. On the next day (sugar capsule after 6th trial) the curve runs on a level of about 29 seconds, some 3 seconds below that of the first morning, beginning to rise at about the time of the sugar dose, and continuing by a gradual ascent until a constant level of 33 seconds is reached—a fatigue of 14 per cent. On the second control day the general tendency is again fatigue, amounting to about 3

seconds (10 per cent.) at the final four trials. Whereas the performance before the caffein dose is slower than that on either of the control mornings, the records after this dose are uniformly better than those of the corresponding periods on control days. The morning trials after the caffein day give the quickest records made during the three days' work. That is to say, the suggestion of Experiment *A* that stimulation is present on the morning after the dose, is further confirmed by the behavior of Squad III. in this intensive experiment.

Squad IV. does not offer such a clear case of stimulation, and this is quite in accord with the results of Experiment *A*, where it was found that the greatest stimulation came from small doses, and where, in fact, the 6 gr. dose did not produce stimulation until the

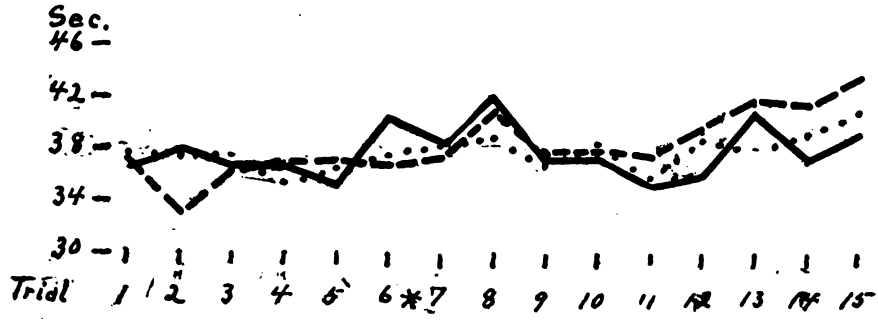


FIG. 23. OPPOSITES TEST. Experiment *B*. Squad IV. (6 gr.)

following morning except with one squad. Generally speaking, it is true of Squad IV. in this Experiment *B*, that whereas the records before the dose and up to three hours or so after the dose follow quite the same level on all three days, after this point the records on the caffein day are 3 to 4 seconds lower than those of the first control day and somewhat lower than those of the second. By far the quickest record made during the three days by this squad occurred on the morning after the caffein dose. The two control days both show fatigue at the last four trials of the day, but on the caffein day none of these records are slower than those made earlier in the day. Thus, for the 6 gr. dose, the effect is the same in kind but less in amount, as compared with that found with Squads I., II., and III.

EXPERIMENT *C*

The results of Experiment *C*, given in Table LI., show no reliable difference between the various types of days. An interesting point in this connection is the absence of sensory stimulation in these mental

processes, as compared with the considerable stimulation found on the plain syrup days in the case of the motor tests. In the case of the opposites test the syrup days do not differ appreciably from the

TABLE LI

OPPOSITES. EXPERIMENT *C*

Giving the average at each hour of the day on the various types of day, the average of the first three trials (before the dose), the average of the last two trials (after the dose) and the ratio of the latter to the former. Dose taken 15 minutes before each of the afternoon trials. Records are averages of 12 subjects.

Dose	Date March	8:00 Sec.	10:00 Sec.	12:00 Sec.	3:10 Sec.	5:20 Sec.	Av. of First 3 Sec.	Av. of Last 2 Sec.	Ratio of Last 2 to First 3 Per Cent.
Blank	6	34.0	32.5	32.2	33.5	34.7	32.9	34.1	103.0
days	11	34.1	33.5	34.3	34.6	34.5	34.0	34.6	101.8
						Av.	33.5	34.4	102.7
Syrup	7	35.7	33.4	35.7	34.4	34.6	34.9	34.5	98.8
days	9	33.1	33.0	33.1	35.1	33.4	33.1	34.3	103.6
						Av.	34.0	34.4	101.1
1.2 gr. caf.	8	33.5	34.9	34.3	34.0	34.2	34.2	34.1	99.7
3.6 gr. caf.	10	32.8	34.0	33.6	33.7	31.6	33.5	32.7	97.6
6 gr. caf.	12	33.9	33.3	35.9	36.5	35.6	34.4	36.1	104.9
						Av.	34.0	34.3	100.8

blank days, two days yielding the same percentage of fatigue (3.6 per cent.) and the other two differing only slightly (blank 101.8 per cent. and syrup 98.8 per cent.). In the case of the 1.2 gr. and 3.6 gr. caffein days, there is again no very clear difference as compared with the blank days or with the syrup days, although the averages turn out slightly quicker. The 6 gr. dose yields the highest percentage of fatigue of any of the 7 days, although the per cent. (4.9) is not reliably different from the large amount (3.6 per cent.) found on both blank and syrup days. On the whole there can not be said to be any caffein influence present, and the effect of sensory stimulation, if there at all, is but slight. The reason for the absence of caffein influence is no doubt to be explained by the fact that, as brought out in the results of Experiments *A* and *B*, the caffein does not begin to affect the processes involved in the opposites test until about 2 to 2.5 hours after the dose when taken in capsule form and about 1 hour after when taken along with syrup as in Experiment *C*. And in this experiment, the drink was taken only 15 minutes before beginning the tests. In the case of the motor tests, where the caffein influence begins more quickly and where sensory stimula-

tion is more effective, the results of Experiment *C* are much clearer than in the present case.

Summary

The influence of caffein on such processes as those involved in the opposites test is stimulation, which begins 1 to 2 hours after the syrup and 2.5 or 3 hours after the capsule dose. The amount of this stimulation, at its maximum, varies from 15 per cent. absolute stimulation to mere counterbalance of a normal fatigue tendency of about the same amount. In general the greatest effect results from the smaller doses. This stimulation is clearly present at the close of day, as much as 6–7 hours after the dose. In both Experiments *A* and *B*, and with all squads, there is evidence that the caffein influence is still operative on the forenoon following, 24 hours or more after the administration of the dose. The magnitude of the caffein influence varies inversely with body weight, and is relatively slight when the dose is taken at 10:30 A.M., somewhat greater when the caffein is taken along with the mid-day lunch, and still greater when the dose is taken in the middle of the afternoon, unaccompanied by food substance.

CHAPTER X

Influence of Caffein on the Calculation Test

The calculation test is more susceptible to the effects of practise than any other of the tests used. Even after the 35 preliminary trials of the first week of the experiment the record for Squad I. falls from as high as 102.7 seconds to as low as 61.2 seconds at the close of Experiment *A*,—a practise drop of 40 per cent. The other squads improve in a similar way, the drops ranging from the 60 per cent. of Squad I. to 32 per cent. for Squad II. This constant improvement through practise is so great as to obscure the caffein effect which the other tests yield in Experiment *A*. Thus the performance after a caffein dose might be speedier than the preceding day's record, but the same effect would be present solely as a result of practise, and there is no way of assigning proportionate results to the two factors. Moreover the records of the following sugar day would surpass those of the caffein day, simply as a result of further practise, and the general effect, when the practise effect is so considerable would not be distinguishable from the irregularities of a normal practise curve. Comparison of calculated with actual records will be consequently less significant than in the other tests, where the practise effect, after the preliminary week, is but slight. The three intensive days, however, occurred at a level of practise sufficiently uniform to yield most unmistakable and consistent results. For the sake of completeness and comparison the results of Experiment *A* are given, in spite of their relative ambiguity.

Experiment *A*

Tables LVI.–LIX. show, for Squads I., III., and IV., the comparison of calculated with actual records, computed as in the case of the Tapping Test, Chapter IV. Table LVI., for the control squad, shows balanced differences at 10:00, 12:00 and 3:10. At the 5:30 period, after sugar doses, the pseudo-caffein days show slightly lower records. The morning trials on pseudo-caffein days are longer, so that if this squad had really had caffein (instead of sugar doses daily) one might be tempted to infer stimulation after the caffein, followed by retardation on the following morning. For Squad III., taking doses of caffein at lunch hour on alternate days, the caffein

TABLE LII

CALCULATION. SQUAD I., EXPERIMENT *A*

	February																		
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
7:45	106.6		94.6	90.2	85.0	84.8	81.3	75.2		71.5	74.9	73.8	66.3	61.9	62.1	60.4	57.4	58.0	58.5
10:00	99.7		94.6	90.5	98.0	84.6	79.1	79.6		75.2	71.1	71.4	75.0	63.4	66.4	65.0	67.2	63.6	62.5
12:00	106.2		95.0	92.8	89.1	88.6	79.2	81.4		77.4	78.4	77.5	71.2	71.7	64.0	62.3	64.5	66.7	67.0
1:00	Sugar doses only, daily.																		
3:10	107.1		100.3	94.0	91.5	87.3	84.9	84.8		79.5	73.2	78.0	75.4	67.6	55.8	69.3	64.1	63.3	60.1
5:30	117.1		105.6	100.2	96.5	92.9	84.1	79.9		77.0	77.4	75.7	80.7	72.2	70.0	71.5	65.2	67.9	62.6

TABLE LIII

CALCULATION. SQUAD II., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	97.5	83.4	*83.0*	*76.3*	*80.5*	71.1	68.9	*66.9*	*63.5*	*59.9*	63.8	52.7	55.5	*52.2*	*49.3*	*48.3*	46.7	46.4	47.1	*48.3*	44.0
10:00	84.3	82.5	*81.4*	*75.6*	*68.1*	69.0	67.4	*65.5*	*67.1*	*54.6*	54.1	51.7	52.3	*51.4*	*49.9*	*50.1*	47.9	48.5	48.3	*46.6*	45.8
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*¼ gr.*	*¼ gr.*	*¼ gr.*	S	S	S	*6 gr.*	S
12:00	85.1	77.8	*76.7*	*82.2*	*71.7*	69.5	65.9	*62.9*	*60.9*	*62.0*	55.2	53.7	50.9	*54.6*	*50.7*	*48.0*	46.1	50.7	46.1	*46.4*	48.0
3:10	87.2	91.1	*81.3*	*75.2*	*75.8*	67.1	61.7	*67.8*	*60.3*	*57.3*	65.8	60.5	53.0	*54.3*	*48.1*	*51.3*	50.3	51.6	51.6	*42.5*	44.7
5:30	91.7	88.7	*96.5*	*75.4*	*77.4*	69.7	71.8	*71.1*	*61.5*	*59.8*	54.2	59.3	54.7	*54.3*	*50.9*	*57.0*	58.7	49.8	50.4	*48.6*	46.7

TABLE LIV

CALCULATION. SQUAD III., EXPERIMENT *A*

	February																	March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	88.3	*77.3*	76.2	*71.5*	74.1	*74.7*	65.6	*64.9*	66.6	*65.9*	58.5	*60.1*	57.9	*60.7*	55.6	*56.5*	55.8	*57.7*	54.6	*51.8*	58.4
10:00	83.6	*78.3*	75.5	*75.9*	77.7	*66.9*	66.8	*64.7*	69.1	*63.5*	63.1	*66.6*	58.5	*59.7*	56.1	*58.7*	54.6	*55.3*	56.0	*54.6*	56.7
12:00	83.5	*78.0*	79.9	*72.9*	68.9	*65.0*	68.3	*66.5*	66.3	*68.9*	63.0	*63.7*	59.4	*60.9*	55.7	*59.7*	63.3	*60.2*	59.2	*55.7*	56.1
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	85.0	*80.0*	74.1	*80.2*	71.9	*68.3*	71.7	*66.0*	67.5	*66.3*	63.0	*60.5*	61.9	*63.6*	64.9	*58.8*	57.5	*54.9*	58.1	*55.6*	55.7
5:30	87.9	*84.7*	75.5	*76.2*	72.1	*67.3*	73.9	*67.8*	67.7	*60.4*	64.7	*65.0*	66.5	*63.5*	62.1	*58.5*	63.3	*56.5*	56.8	*56.9*	54.2

TABLE LV

CALCULATION. SQUAD IV., EXPERIMENT *A*

	February																			March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	77.6	*73.0*	66.9	*67.4*	64.3	*62.1*	56.9	*61.9*	57.2	*55.4*	55.0	*51.9*	54.4	*49.2*	50.8	*49.0*	51.6	*46.3*	47.6	*46.5*	46.6
10:00	78.7	*73.2*	68.6	*69.0*	62.3	*61.4*	59.4	*61.7*	58.4	*58.8*	57.9	*57.0*	55.8	*54.6*	54.8	*52.1*	50.3	*51.3*	48.5	*50.9*	46.6
12:00	78.5	*71.3*	68.5	*68.2*	63.1	*65.8*	60.9	*62.6*	59.2	*59.9*	55.8	*54.1*	52.7	*52.0*	50.2	*54.6*	50.1	*49.1*	49.0	*50.3*	47.7
1:45	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	78.1	*74.4*	70.2	*69.5*	64.2	*63.3*	60.9	*57.8*	61.4	*57.9*	56.0	*56.8*	52.4	*52.1*	51.8	*49.9*	49.9	*47.9*	49.1	*48.2*	47.7
5:30	77.6	*73.4*	69.2	*69.6*	67.2	*67.9*	63.5	*59.7*	60.8	*57.6*	57.2	*53.3*	56.3	*53.3*	53.3	*50.6*	49.6	*49.2*	49.4	*49.9*	48.4

TABLE LVI

Calculation. Squad I

	7:45			10:00			12:00			3:10			5:30		
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	1:00 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
93.0	89.8	+ 0.2	91.4	96.3	— 4.9	95.1	92.1	+ 3.0	S	95.7	95.9	— 0.2	102.7	101.1	+ 1.6
77.6	76.4	+ 1.2	78.8	77.2	+ 1.6	82.5	78.3	+ 4.2	S	82.6	82.2	+ 0.4	82.6	80.6	+ 2.0
69.1	68.2	+ 0.9	71.0	71.2	— 0.2	74.6	76.7	— 2.1	S	74.9	76.9	— 2.0	78.4	76.0	+ 2.4
62.6	61.2	+ 1.4	65.7	64.2	+ 1.5	67.5	67.0	+ 0.5	S	62.9	68.5	— 5.6	70.0	71.9	— 1.9

TABLE LVII

Calculation. Squad II

Trial	7:45	10:00	10:30 Dose	12:00	3:10	5:30	Trials
Averages	66.1	63.1	Sugar	62.5	65.6	67.5	11
at the	79.9	75.0	1 gr. Caf.	76.9	77.4	83.1	3
successive	63.4	62.4	2 gr. Caf.	61.9	61.8	64.1	3
trials	49.9	50.5	4 gr. Caf.	51.1	51.2	54.1	3
	46.2	46.2	6 gr. Caf.	47.2	43.6	47.7	1

TABLE LVIII

CALCULATION. SQUAD III

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:20 Caf. Av.	Dif.
78.8	74.4	+ 4.4	78.1	77.1	+ 1.0	78.1	75.5	+ 2.6	1 gr.	76.3	80.5	— 4.2	77.8	80.5	— 2.7
68.0	69.8	— 1.8	70.2	65.8	+ 4.4	68.0	65.8	+ 2.2	2 gr.	70.7	67.2	+ 3.5	71.9	67.6	+ 4.3
60.4	63.0	— 2.6	63.5	65.1	— 1.6	63.0	66.3	— 3.3	3 gr.	63.9	63.4	+ 0.5	65.9	62.7	+ 3.2
56.3	58.6	— 2.3	56.4	59.2	— 2.8	58.6	60.3	— 1.7	4 gr.	62.3	61.2	+ 1.1	63.5	61.0	+ 2.5
55.9	54.8	+ 1.1	55.9	55.0	+ 0.9	59.5	58.0	+ 1.5	6 gr.	57.4	55.3	+ 2.1	57.8	56.7	+ 1.1

TABLE LIX

CALCULATION. SQUAD IV

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:45 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:20 Caf. Av.	Dif.
69.0	70.2	— 1.2	69.6	71.1	— 1.5	69.7	69.8	— 0.1	1 gr.	70.7	72.0	— 1.3	70.9	71.5	— 0.6
58.9	62.0	— 3.1	59.9	61.6	— 1.7	61.1	64.2	— 3.1	2 gr.	61.9	60.6	+ 1.3	63.8	63.8	0.0
55.4	53.7	+ 1.7	57.6	57.9	— 0.3	55.9	57.0	— 1.1	3 gr.	56.5	57.4	— 0.9	57.9	55.5	+ 2.4
51.9	49.1	+ 2.8	53.8	53.3	+ 0.5	50.9	53.3	— 2.4	4 gr.	51.5	51.0	+ 0.5	53.2	52.0	+ 1.2
48.4	46.4	+ 2.0	48.5	51.1	— 2.6	49.0	49.7	— 0.7	6 gr.	48.6	48.2	+ 0.4	49.2	49.6	— 0.4

records are superior at both afternoon trials, except for 1 gr. doses. If this be taken to indicate stimulation there is no evidence of any sort of after effect on the following days. The morning trials do not differ from each other in any consistent way. The records for Squad IV. show no differences between caffein and control days for the trials after the doses. There is absolutely no evidence of stimulation so far as the figures are concerned. At 10:00 and 12:00 the signs of difference are all —, but the amounts are small. Perhaps the only conclusion to be safely drawn from the table is that there is no evidence of any deleterious caffein effect. Table LVII. gives for Squad II., for each of the five trials, the average performance on the various types of days. The general tendency (see Sugar days) is for the morning record to be slow, for the 10:00 and 12:00 records to be good, while the afternoon and evening trials return to the poorer level of the 7:45 test, or indeed are slightly inferior to that record. The records after 1 gr. of caffein show no departure from this tendency. But, after 2, 4 and 6 gr. doses at 10:30, there is a consistent tendency for the 3:10 record to improve rather than to fall. In fact after 2 and 6 gr. the 3:10 trial produces the best record of the day, and after 6 gr. the normal fatigue is clearly relieved, the usual falling off not coming until 5:30. All the evidence of this table, as of the preceding to a less degree, goes to suggest stimulation as the characteristic effect of caffein on the calculation test.

TABLE LX

CALCULATION. SQUAD I., EXPERIMENT *A*

Ratio between performance after dose to performance before dose

Subj.	Control Days	M.V.	Pseudo-Caffein Days	M.V.
1	1.044	.051	1.064	.038
4	1.019	.038	.973	.040
7	1.097	.035	1.075	.048
15	1.094	.064	1.117	.082
Average	1.051	.047	1.057	.052

The tendency of the caffein influence to be obscured by the practise effect, in this test, is much reduced when the standard of performance is taken to be the average record made before the dose, on any given day, rather than the corresponding records of other days. Tables LX.–LXIV. give the results for all squads, when this method of measurement is adopted. The ratio of the records after the dose to those before the dose, when these ratios for control days are compared with the ratios for caffein days, will afford a general view of the effect of the dose on the total afternoon's work. The only defect

of this method is that it gives no information as to the time relations of the drug influence, which information must come from the application of the preceding method and from the results of the intensive experiment. Table LX. gives the results of the control squad, computed by this ratio method. The two ratios (for control days and for pseudo-caffein days) are practically identical, such difference as is present (0.006) being in favor of the control days.

TABLE LXI

CALCULATION. SQUAD II., EXPERIMENT *A*

Average of 12:00 and 3:10 records compared with average of 8:00 and 10:00 records. Dose at 10:30

Subj.	Control Average	M.V.	1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.	Caf. Av.	Cont. Av. —Caf. Av.
8	1.031	.031	.981	.017	.962	.020	1.017	.043	.936	.974	—.057
12	.982	.031	.955	.120	.977	.073	1.011	.043	.986	.982	.000
13	1.010	.076	1.057	.056	1.025	.116	1.022	.050	.896	1.000	—.010
Av.	1.008	.046	.998	.074	.988	.069	1.016	.045	.939	.985	—.022

TABLE LXII

CALCULATION. SQUAD II., EXPERIMENT *A*

5:30 records compared with average record before dose

Subj.	Control Average	M.V.	1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V	6 Gr.	Caf. Av.	Cont. Av. —Caf. Av.
8	1.134	.068	1.024	.040	.987	.043	1.050	.057	1.085	1.036	—.098
12	1.005	.080	.905	.060	1.063	.130	1.013	.026	1.015	.999	—.006
13	1.025	.101	1.265	.240	1.025	.086	1.158	.123	.976	1.106	+.081
Av.	1.055	.082	1.064	.113	1.026	.086	1.070	.068	1.025	1.046	—.009

Squad II. (Tables LXI., LXII.) yields, for the total range of doses, an average stimulation of 2.2 per cent. for the earlier tests. The slightest subject (No. 8, 144 lbs.) averages 5.7 per cent., while the other two (160 and 175 lbs.) show only a slight influence, No. 12, in fact showing no difference at all between the control and the caffein averages. By the time of the 5:30 record (Table LXII.) the balance of stimulation is only .9 per cent., subject 13 being poorer on caffein days. The greatest stimulation, with this squad, comes from the 6 gr. dose.

The three individuals of Squad III. all show stimulation. This effect is greatest for subject 9 (130 lbs.), less for subject 3 (159 lbs.) and still less for the heaviest subject, No. 14 (193 lbs.). The squad average is 2.1 per cent. stimulation for the total range of doses, and the stimulation does not appear until after the doses larger than 1 gr.

Squad IV. yields an average stimulation, for all doses, of 1.9 per

cent. The greatest stimulation is shown by subjects 5 and 6 (average weight 115 lbs.). Subjects 10 and 11 (average 133.5 lbs.) show somewhat less stimulation, while the heaviest individual, sub-

TABLE LXIII

CALCULATION. SQUAD III., EXPERIMENT *A*

Ratio between performance after dose to performance before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Caffein Average	Dif. Betw. Cont. and Caf.
3	1.063	.046	1.135	1.012	1.015	1.132	1.059		
			1.055	1.047	1.077	.995	1.058		
			1.095	1.029	1.046	1.063	1.058	1.058	—.005
9	1.024	.071	.997	.954	.861	1.024	.960		
			1.012	1.144	.866	.997	1.007		
			1.004	.999	.863	1.010	.983	.971	—.053
14	1.009	.050	1.037	.985	.999	1.000	.888		
			1.114	.989	.983	1.024	1.051		
			1.075	.987	.991	1.012	.969	1.007	—.002
Av.	1.032	.055	1.058	1.005	.966	1.028	1.003	1.012	—.021

TABLE LXIV

CALCULATION. SQUAD IV., EXPERIMENT *A*

Ratio between performance after dose to performance before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Caffein Average	Dif. Betw. Cont. and Caf.
5	1.012	.054	1.059	1.038	1.060	.973	.893		
			1.048	.969	.966	.929	Absent		
			1.053	1.003	1.013	.951	.893	.982	—.030
6	1.050	.040	1.020	1.089	1.049	1.071	.980		
			1.022	.945	1.000	.930	1.080		
			1.021	1.017	1.024	1.000	1.030	1.018	—.032
10	1.051	.045	1.008	1.054	1.035	.996	1.146		
			1.006	.980	.987	1.056	1.051		
			1.007	1.017	1.011	1.026	1.098	1.031	—.020
11	.978	.044	.942	.970	.943	.943	.967		
			.967	.933	1.099	.964	1.028		
			.954	.951	1.021	.953	.997	.955	—.023
16	1.004	.039	1.087	1.026	.900	1.121	.985		
			1.062	.905	1.042	.964	.998		
			1.074	.960	.971	1.042	.992	1.007	+.003
Av.	1.019	.044	1.021	.989	1.008	.994	.994	1.000	—.019

ject 16 (weight 174 lbs.), shows hardly any influence at all (.3 per cent. in favor of the control days). As in the case of Squad III. the greatest stimulation comes from the larger doses.

The mere suggestion of stimulation resulting from the previous method of treating the data, is thus not only most clearly confirmed by this second method, but the influence of body weight on the magnitude of the caffein influence is again made apparent. So far as this test is concerned there is no indication that the effect varies with the time of day nor with the conditions of administration of the dose.

Experiment *B*

The correctness of these conclusions is amply proven by the results of the three intensive days (Experiment *B*) given in the following curves. The first set of curves show the records for the control squad (I.) which ran for the first two days (March 3 and 4) on

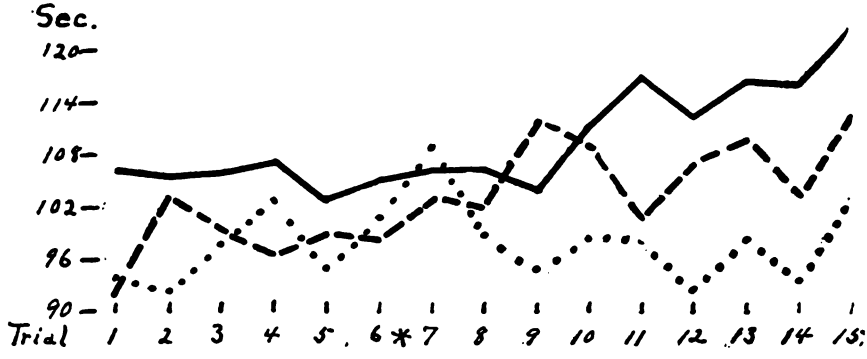


Fig. 24. Calculation Test. Experiment *B*. Squad I. (Control.)

sugar capsules. The curves for these two days are thoroughly representative of the normal tendency to fatigue in the calculation test. The amount of this fatigue rises to about 20 per cent. at the close of the control days. But on the third day (March 5) this squad received 3 gr. of caffein (capsule) after the 6th trial and 2 gr. more after the 12th trial. Up to the time of the first dose the normal fatigue tendency is clearly showing itself again. But at the 9th trial, 2.25 hours after the dose, this fatigue tendency is seen to be counterbalanced by a stimulation which carries the curve downward instead of upward, the subsequent records being considerably superior to those of the earlier trials. After the 2 gr. dose late in the evening, the record equals that of the best of the morning trials. Nothing can be said concerning the after effect of this stimulation

in the case of this squad, since this was the last day of the intensive experiment. That there is still a practise effect on the test as a whole is indicated by the tendency for the general level of the curves to drop lower and lower on successive days. This tendency is, however, by this time so slight that it is quite insufficient to obscure the caffein effect. Within a given day the normal tendency is fatigue rather than practise.

Squad II., on March 3, shows the characteristic fatigue curve beginning. After the 6th trial the dose was taken (1.2 gr. caffein with syrup and carbonated water). After the 7th trial (45 minutes later) the curve falls instead of continuing to rise, subsequent records being superior to any made before the dose and the final level being much lower than that of the morning. On the following day

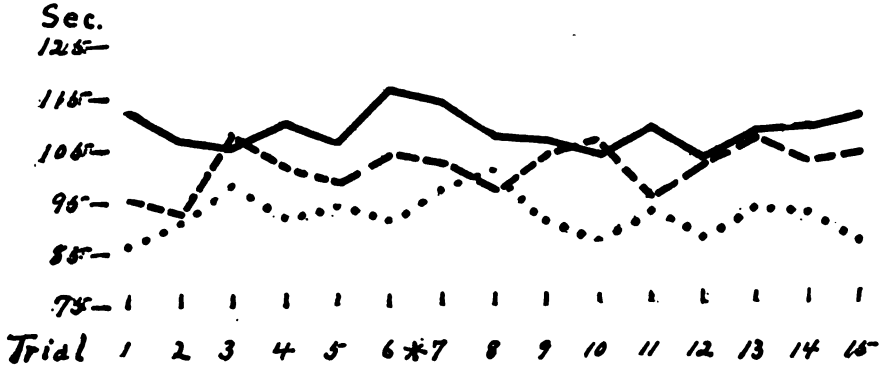


FIG. 25. CALCULATION TEST. Experiment *B*. Squad II. (Solution.)

(March 4, sugar dose after 6th trial) there is no sign of disastrous after effect. On the contrary the curve starts out on a level some 10 per cent. lower than that of the previous morning. This is, without doubt, simply the general practise effect which is present with all the squads. The curve for this second day, however, contrasts with that of March 3 by following the normal fatigue course so clearly demonstrated in the case of Squad I. In spite of the 10 per cent. superiority of the morning performance the afternoon and evening work is hardly better than that of the day before. On the 3d day (March 5) the normal fatigue curve begins again. This time the dose was once more a syrup with caffein. After the 8th trial (1.5 hr. after the dose) the curve sweeps downward at a most surprising rate, a stimulation of about 16 per cent. being present on the very last trials of the day, over 6 hours after the dose.

Squad III. (3 gr. caffein capsule March 3, sugar thereafter)

shows the same sort of influence. The control days afford fatigue curves of quite the normal shape, but the caffein curve fails to rise to the same degree as the day progresses, the best record of the day being made late in the afternoon, 3 hours after the dose. No after

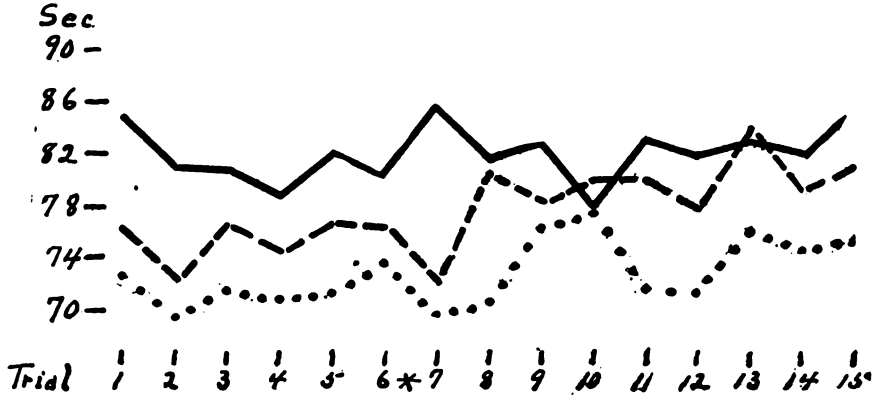


FIG. 26. CALCULATION TEST. Experiment *B*. Squad III. (3 gr.)

effect is observable. The general levels of the curves fall slightly from day to day, probably due again to simple practise effect.

If the effect of the 3 gr. caffein dose on Squad III. is obvious, the results of twice that amount on Squad IV. are doubly apparent.

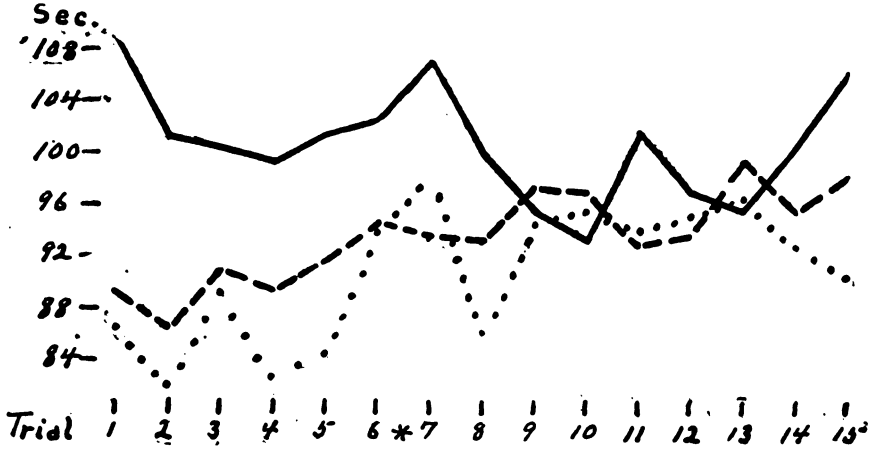


FIG. 27. CALCULATION TEST. Experiment *B*. Squad IV. (6 gr.)

The 6 gr. dose was taken after the 6th trial on March 3. At the 9th trial, 2.25 hours after the dose, the record has fallen to 6 or 7 per cent. below the previous level and remains there for the rest of the day. On

the following morning, presumably as the result of general practise, the curve begins at about 10 per cent. lower than on the first day, gradually rising to show 8–10 per cent. fatigue by the time of the dose (sugar). But instead of falling off now, as did the caffein curve, the level continues to rise until the fatigue amounts to about 13 per cent. The afternoon and evening records of this second day are not superior to those of the caffein day preceding, in spite of the 10 per cent. advantage with which the day's work began. The second control curve (March 5) follows the familiar course of fatigue, the late records of the day being 15 or 16 per cent. inferior to those made earlier in the day.

Experiment *C*

The results of Experiment *C*, in which the doses were administered solely in liquid form, before each of the afternoon tests, are given in Table LXV. In order to show any possible individual differences the results are given separately for each subject. The average of the forenoon trials is taken as the norm for the day's work. The average of the two trials following the doses is compared with this norm, the table giving the afternoon average in terms of per cent. of the norm for the corresponding day.

TABLE LXV

Calculation. Experiment *C*

Giving performance after dose, in per cent. of work before dose

Subject		1	3	4	7	8	9	10	11	12	13	14	15	Average
2 blank		103	104	86	100	106	101	102	103	97	89	108	105	100.0
days		104	101	98	111	106	102	104	115	Abs.	124	103	112	107.2
	Av.	103.5	102.5	94	105.5	106	101.5	102	109	97	106.5	105.5	108.5	103.6
2 syrup		106	107	96	102	107	104	99	106	95	95	102	99	101.0
days		106	101	100	112	96	107	111	95	107	99	99	99	102.0
	Av.	106	104	98	107	101.5	105.5	105	100.5	101	97	100.5	99	101.5
1.2 gr. caf.		107	96	100	104	107	100	101	100	99	91	100	109	101.0
3.6 gr. caf.		104	98	89	104	99	105	99	94	100	106	92	99	99.5
6.0 gr. caf.		97	105	93	94	117	105	100	102	Abs.	122	108	99	103.1
Caffein Av.		102.7	99.7	94	100.7	107.7	103.3	100	98.7	99.5	106.3	100	102.3	101.2

On the blank days (no dose) the fatigue tendency amounts to an average of 3.6 per cent. for the two days, a much lower figure than was obtained in Experiment *B*, where there were 15 performances daily instead of 5 as in the present case. Only with two of the twelve subjects is there increased rapidity instead of fatigue. On plain syrup days the average performance shows slighter fatigue

(1.5 per cent.) than on blank days. In 10 of the 24 records there is absolute stimulation. Comparing, in the case of each individual, the syrup average with the average for the blank days, thus securing a measure of relative effect, a relative stimulation of 2 per cent. or over is found in 5 cases, but in the same number of cases the opposite effect is found. The plain syrup seems on the whole to quicken slightly the speed of performance.

The 1.2 gr. caffein dose yields an average record but .5 per cent. better than the plain syrup, or 2.6 per cent. better than the record for blank days. Such absolute fatigue (1 per cent.) as is present is due to the four individuals, 1, 7, 8 and 15, all but one of whom were retarded by the plain syrup doses, both absolutely and as compared with blank days.

The 3.6 gr. dose results in an absolute stimulation of .5 per cent., a record 4.1 per cent. better than that secured on blank days. The only exceptions to this stimulation are again subjects 1 and 7, along with 9 and 13, all but one of whom (13) showed retardation after plain syrup doses. After the 6 gr. dose the average amount of fatigue (3.1 per cent.) is only .5 per cent. less than the average for blank days, and is greater than that after plain syrup, 1.2 gr., and 3.6 gr. of caffein. Subjects 3, 8, 9, 13 and 14 show considerable absolute retardation and also relative retardation as compared with either the blank days or with the sugar days, although of these subjects 3, 8 and 14 had shown stimulation from smaller doses. Subjects 1, 4, 7, 10 and 15 show, on the other hand, considerable stimulation, both absolute and as compared with blank and syrup days. In fact, if the records of subjects 8 and 13 be omitted, the average performance for the squad after the dose is only 100.3 per cent. of the normal. The calculation test apparently affords instances of individual differences which may be taken up with profit in an appropriate place. It should be remembered that the 6 gr. of caffein, in this Experiment *C* was taken along with 5 ounces of the heavy syrup and two glasses of the carbonated water. This is much more syrup than was taken on plain syrup days. It would not be at all surprising if such a large amount of the syrup and water would fail to produce the sensory and psychic stimulation found when more agreeable amounts are taken.

Summary

The results of all four squads in Experiment *B* are thus found to confirm the suggestions of Experiment *A*. All squads reveal a most pronounced stimulation following caffein. This stimulation amounts

to a considerable per cent. of the initial performance, whereas the normal tendency, on control days, results in a corresponding degree of fatigue instead. The stimulation begins about 1 hour after the dose, when the caffein is taken in solution with syrup and carbonated water, and 2.25 to 2.5 hours after when the dose is in capsule form. The effect is still present at the close of the day's work, 6–7 hours after the dose. No evidence of any secondary depression is found. Instead the morning after the dose shows, without exception, a clear improvement over the work of the preceding morning. As pointed out above, it should perhaps be concluded that this superiority is due to general practise in the test. But it is interesting to find that this general practise effect, if such it be, is much greater after the caffein day than on the day following the sugar dose only. Another curious thing about this result is the further fact that the practise improvement, at least so far as the record shows it, seems to come during the night intermission, between the series of trials. The normal tendency at successive trials on the same day is fatigue rather than increase in speed. In fact there is considerable justification for supposing that the influence of the caffein dose, which is seen to be unmistakably present 6 or 7 hours after administration, is still operative on the following day. This operation might be in the form of a real persistence of stimulation or in the form of increased efficiency due to skill or disposition acquired during the stimulation of the preceding day. The former hypothesis would not be inconsistent with the data available concerning the length of time caffein may remain in the system after ingestion. If this be taken to be a real persistence, one is at once interested to know why the effect on motor processes seems to be so much more transient than that manifested in this more strictly mental performance. The results of Experiment *A*, when computed by the ratio method, afford further evidence of the fact that the magnitude of the caffein influence varies inversely with the body weight of the individual tested.

CHAPTER XI

The Influence of Caffein on Discrimination and Choice Reaction Times

In this test the average of 10 correct reactions to the blue disc was taken as constituting the record for a given period. Reactions to the red disc were recorded only as being larger or smaller than a stated magnitude. Since these red exposures served only as control stimuli and varied in number from test to test, they are of no particular interest or value. The reactions to the blue disc were measured in sigma, the mean variations of the 10 trials were computed, and the number of false reactions at each sitting noted.

Experiment *A*

In Experiment *A*, on February 13, at the 10:00, 3:10 and 5:30 tests, an accident to the instrument rendered the reactions invalid. Hence for those three periods the records of the preceding day of the same type (1 gr. caffein) were substituted in computing the averages and in comparing actual with calculated records. Tables LXVI.–LXXIII. show for all squads of Experiment *A* the results from the point of view of discrimination time.

Squad I. (control) shows, as is to be expected, only chance differences between the control days and the pseudo-caffein days. For all hours of the day the differences between actual and computed records are divided in sign between + and —, in a random way, and the magnitudes of these differences are in most cases small.

Squad II. shows, on control days, at the trials after the sugar dose, a reaction time uniformly 92 per cent. of the daily normal (average of the two trials preceding the dose). For caffein doses of 1–4 gr. the reactions after the dose are considerably slower as compared with control days, ranging from 96 per cent. to 104 per cent. of the morning performance. In the case of the largest dose (6 gr.) this retardation is not present, the trials after the dose being 90 per cent. as quick as those before, an average which quite resembles that of the control days or is even a little better, suggesting stimulation instead. The general character of the caffein influence seems to be retardation except for the large dose. This squad took caffein on three successive days at 10:30 A.M., in each case the caffein trio being followed by a corresponding number of control days.

TABLE LXVI

DISCRIMINATION REACTION. SQUAD I., EXPERIMENT *A*

	February																		
	10	11	12	13	14	15	16	17	18	19	20	21	23	23	24	25	26	27	28
7:45	330.0	323.2	361.7	351.0	359.5	349.5	313.5	318.7	309.0	330.0	340.7	319.7	313.2	317.0	312.7	313.5	354.8	360.5	330.8
10:00	333.5	335.7	326.7	335.7	345.5	314.2	284.2	302.2	313.2	329.5	321.5	318.5	310.2	307.0	313.5	316.2	348.7	364.0	342.5
12:00	332.7	327.2	330.7	351.2	364.2	345.5	322.5	333.0	330.7	323.5	326.0	294.0	311.2	323.5	326.0	324.0	354.0	347.3	321.0
1:00	Sugar doses only, daily.																		
3:10	319.7	336.0	335.5	336.0	349.5	337.2	310.7	320.2	364.0	330.0	328.2	303.0	314.5	321.7	318.5	332.8	363.3	362.3	335.8
5:30	349.7	369.5	335.0	369.5	360.5	357.2	358.7	361.5	355.5	349.7	348.7	316.7	302.7	343.2	349.5	341.2	349.7	331.5	334.8

TABLE LXVII

DISCRIMINATION REACTION. SQUAD II., EXPERIMENT *A*

	February																	March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	303.3	302.0	*343.7*	*356.3*	*325.0*	304.3	304.0	*300.0*	*295.0*	*306.7*	317.0	285.3	280.7	*291.0*	*300.3*	*323.3*	327.0	356.0	325.7	*332.3*	278.3
10:00	319.3	283.7	*329.3*	*283.7*	*354.2*	294.3	288.7	*303.3*	*289.7*	*278.3*	281.3	290.3	266.7	*282.7*	*309.7*	*298.7*	309.3	374.3	303.0	*316.0*	320.0
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*¼ gr.*	*¼ gr.*	*¼ gr.*	S	S	S	*6 gr.*	S
12:00	308.0	227.7	*321.7*	*323.7*	*331.3*	292.0	306.7	*288.3*	*302.7*	*282.3*	281.3	283.7	272.0	*824.3*	*299.7*	*287.7*	317.7	329.3	327.7	*295.3*	298.0
3:10	322.3	306.3	*351.0*	*306.3*	*298.7*	297.0	285.7	*301.0*	*305.0*	*288.7*	279.0	280.3	277.7	*295.0*	*296.7*	*288.3*	327.0	345.0	315.7	*292.7*	299.7
5:30	306.0	335.7	*348.0*	*335.7*	*315.0*	309.3	316.7	*310.7*	*302.0*	*291.7*	299.0	283.7	275.3	*304.7*	*324.3*	*306.6*	315.0	301.3	307.0	*293.0*	307.0

TABLE LXVIII

DISCRIMINATION REACTION. SQUAD III., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	309.0	*320.7*	361.0	*335.3*	335.3	*325.0*	320.3	*313.0*	310.0	*324.7*	335.0	*321.3*	290.0	*321.7*	342.3	*346.3*	340.3	*347.3*	344.0	*333.3*	327.3
10:00	325.3	*321.3*	357.0	*321.3*	342.7	*313.7*	338.0	*318.7*	317.0	*315.7*	328.0	*309.7*	340.3	*341.3*	332.0	*345.3*	354.0	*374.3*	337.7	*334.3*	330.7
12:00	322.7	*329.0*	306.7	*341.0*	344.7	*329.0*	332.7	*301.7*	320.3	*334.3*	321.3	*307.7*	327.3	*328.0*	331.7	*309.3*	350.0	*353.0*	322.0	*324.0*	326.0
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	329.3	*334.7*	334.0	*334.7*	335.3	*353.3*	338.0	*305.3*	306.0	*329.7*	303.3	*301.3*	309.3	*324.3*	319.7	*321.3*	345.0	*343.3*	346.3	*297.7*	344.7
5:30	311.7	*344.0*	340.3	*344.0*	346.0	*346.3*	343.3	*357.7*	324.7	*348.0*	324.7	*331.3*	322.3	*347.0*	348.7	*330.7*	342.0	*359.7*	326.0	*331.0*	341.0

TABLE LXIX

DISCRIMINATION REACTION. SQUAD IV., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	321.2	*299.8*	344.8	*351.6*	331.6	*323.0*	313.8	*294.6*	312.8	*304.8*	302.2	*302.6*	295.6	*303.4*	295.6	*318.6*	337.6	*332.4*	347.6	*336.6*	323.0
10:00	295.4	*296.0*	347.0	*296.0*	323.8	*306.2*	314.6	*299.0*	321.4	*288.8*	306.0	*314.8*	316.2	*297.4*	317.0	*321.6*	336.2	*355.4*	352.4	*322.4*	326.2
12:00	294.4	*285.8*	339.8	*334.4*	300.6	*302.8*	297.6	*285.6*	342.4	*299.8*	290.2	*292.2*	288.4	*303.6*	306.2	*328.2*	339.2	*353.0*	322.6	*308.8*	317.0
1:45	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	293.2	*299.6*	320.6	*299.6*	324.0	*310.2*	312.4	*308.6*	320.4	*296.2*	308.8	*307.4*	297.0	*298.8*	325.8	*326.4*	336.4	*329.4*	349.8	*329.4*	344.0
5:30	308.0	*333.4*	323.6	*333.4*	315.2	*331.4*	308.4	*320.6*	314.0	*315.2*	308.4	*311.6*	305.6	*320.6*	332.0	*335.8*	342.8	*339.6*	342.2	*340.2*	322.4

TABLE LXX

DISCRIMINATION. SQUAD I., EXPERIMENT *A*

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug. Av.	5:20 Caf. Av.	Dif.
353.3	337.1	+16.2	333.1	335.7	+2.6	339.6	339.2	+ 0.4	1 gr.	335.1	336.0	— 0.9	345.1	369.5	+24.6
323.9	334.1	—10.2	306.8	308.2	—1.4	335.5	339.3	— 3.8	2 gr.	333.8	328.7	+ 0.1	358.4	359.4	— 1.0
325.9	324.9	+ 1.0	316.7	324.0	—7.3	323.5	308.8	+14.7	3 gr.	333.8	316.5	+17.3	338.9	333.2	+ 5.7
323.4	315.3	+ 8.1	321.5	311.6	+9.9	329.3	323.8	+ 5.5	4 gr.	328.7	327.3	+ 1.4	337.9	342.2	— 4.3

TABLE LXXI

DISCRIMINATION. SQUAD II., EXPERIMENT *A*

Dose	Average of 7:45 and 10:00	12:00 Per Cent.	3:10 Per Cent.	5:20 Per Cent.	No. of Trials
Sugar	329.4	91	92	93	11
1 gr.	338.0	97	96	99	3
2 gr.	295.8	98	101	102	3
4 gr.	309.0	97	98	104	3
6 gr.	324.2	91	90	90	1

TABLE LXXII

DISCRIMINATION. SQUAD III., EXPERIMENT *A*

7:45			10:00			12:00				3:10			5:30		
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	1:00 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
341.6	328.0	+13.6	345.6	321.3	+24.3	320.2	335.0	—14.8	1 gr.	333.2	334.7	— 1.5	334.6	344.0	— 9.4
321.5	319.0	+ 2.5	334.0	316.2	+17.8	332.6	315.4	+17.2	2 gr.	329.4	329.3	+ 0.1	339.4	352.0	—12.6
317.5	323.0	— 5.5	328.4	312.7	+15.7	322.6	321.0	+ 1.6	3 gr.	305.5	315.5	—10.0	324.1	339.7	—15.6
328.8	334.0	— 5.2	339.6	343.3	— 3.7	335.2	318.7	+16.5	4 gr.	323.5	322.8	+ 0.7	340.5	338.9	+ 1.6
339.0	340.3	— 1.3	340.1	354.3	—14.2	330.0	338.5	— 8.5	6 gr.	345.6	320.5	+25.1	333.8	335.4	— 1.6

TABLE LXXIII

DISCRIMINATION. SQUAD IV., EXPERIMENT *A*

7:45			10:00			12:00				3:10			5:30		
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	1:45 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
335.6	325.7	+9.9	328.3	296.0	+32.3	318.7	310.1	+ 8.6	1 gr.	314.6	299.6	+15.0	317.6	333.4	—15.8
318.0	308.8	+9.2	318.6	302.6	+16.0	309.6	294.2	+15.4	2 gr.	317.3	309.4	+ 7.9	311.5	326.0	—14.5
303.2	303.7	—0.5	312.4	301.8	+10.6	302.8	296.0	+ 6.8	3 gr.	308.8	301.8	+ 7.0	309.1	313.4	— 4.3
306.1	311.0	—4.9	321.6	309.5	+12.1	310.0	315.9	— 5.9	4 gr.	321.3	312.6	+ 8.7	328.1	328.2	— 0.1
334.4	334.5	—4.4	339.0	338.9	+ 2.1	327.6	330.9	— 5.9	6 gr.	341.3	329.4	+15.6	336.3	339.9	— 2.7

In the case of Squad III., taking dose with lunch on alternate days, the 3:10 test, 2 hours after the dose shows no consistent differences between caffein and control days, except a strong suggestion of stimulation from the 6 gr. dose (difference + 25). This result is in line with the lack of retardation from 6 gr. in the case of Squad II. Indeed, in the case of that squad also, the record after 6 gr. was slightly better than on control days (90 per cent. of the morning average as compared with 92 per cent.). At the 5:30 period, in the case of this Squad III., all but one of the signs are —, denoting slower reactions on caffein days, the differences decreasing in magnitude with the larger doses, quite confirming, again, the results from Squad II. At 7:45 on the following morning the differences are (except for the smallest dose) very small (never over 5.5 sigma), and the signs balance. At 10:00 and 12:00 again there is no consistent difference between the two types of days. If there is any after effect at all here, it is a tendency to continued retardation from the small doses and possibly toward stimulation from the large doses which had on the previous day scarcely any effect. In general this squad suggests a retardation about 4.5 hours after the dose, with no clear evidence of after effect.

Squad IV., taking the dose on empty stomach in mid afternoon, shows at 3:10, clear evidence of stimulation for all doses. But by 5:30 this effect has given place to such retardation as that found in the case of Squad III. The amount of this retardation, as also in the case of Squad III., decreases in amount with the larger doses. On the following morning the small doses, which had produced retardation on the preceding evening, seem to show a persistence of this effect. The larger doses, which made but little difference at the 5:30 trial, show no clear effect on the following day. The retardation for small doses is still present at 10:00 and 12:00. The general effect of the caffein on this squad seems then to have been an initial stimulation, followed by retardation for small doses and by balance for large doses. This effect is still present during the following forenoon. The large dose seems to produce so much initial stimulation that the subsequent retardation which characterizes the smaller doses is absent. The same thing was found in the case of Squad III. In both these squads, when retardation is present, it decreases in amount for the larger dose, and when stimulation is present the reverse relation is the case. The only difference between Squad III. and Squad IV., in Experiment *A*, consists in the absence of the initial stimulation from small doses in the case of Squad III. Both these squads agree with Squad II. in showing retardation from small doses but not from large.

If now the standard of comparison be taken to be the performance before the dose, rather than the corresponding records on other days, and the comparisons be presented in the form of ratios, the results presented in Tables LXXIV.–LXXVIII. are obtained. In the case of the control squad (Table LXXIV.) two subjects show relative superiority for the control days and two for the pseudo-caffein days, the squad average being 1.7 per cent. in favor of the control days.

TABLE LXXIV

DISCRIMINATION. SQUAD I., EXPERIMENT *A*

Ratios of reaction times after dose to times before dose

Subj.	Control Av.	M.V.	Pseudo-Caf. Av.	M.V.
1	.999	.036	1.026	.033
4	1.035	.038	1.022	.037
7	1.059	.071	1.014	.065
15	1.020	.087	1.120	.052
Average	1.028	.058	1.045	.046

TABLE LXXV

DISCRIMINATION. SQUAD II., EXPERIMENT *A*

Ratios of times after dose to times before dose. 12:00 and 3:10

Subj.	Control Average	M.V.	1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.	Caffein Av.	Dif
8	1.015	.047	.946	.070	.980	.023	.994	.023	.854	.943	—.072
12	.997	.060	.939	.040	1.063	.027	.973	.017	.928	.976	—.023
13	.955	.058	.925	.080	.937	.033	.947	.047	.945	.938	—.017
Av.	.989	.055	.933	.063	.996	.027	.971	.029	.909	.952	—.037

TABLE LXXVI

DISCRIMINATION. SQUAD II., EXPERIMENT *A*

Ratio of the 5:30 record to record before dose

Subj.	Control Average	M.V.	1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.	Caffein Av.	Dif.
8	1.016	.072	.986	.047	.997	.027	1.047	.057	.766	.949	—.067
12	1.023	.048	.977	.077	1.076	.007	1.031	.053	.978	1.000	—.023
13	.971	.087	.883	.017	.993	.053	1.034	.100	.989	.975	+.004
Av.	1.003	.069	.948	.047	1.022	.029	1.037	.070	.911	.975	—.028

Squad II. shows, at the 12:00 and 3:10 periods (Table LXXV.), stimulation for all caffein doses, the average amount being 3.7 per cent., and the effect being greatest for the 1 and 6 gr. amounts. At 5:30 (Table LXXVI.) two of the subjects still show stimulation, while the third shows no stimulation except from the 1 gr. dose, the other doses being inferior to the performance on control days. Here again, in the squad averages, the stimulation comes from the 1 and

6 gr. amounts only, the 2 and 4 gr. producing retardation. In this case then, we have the only contradiction between the results of Experiment *A* as computed by the two methods. The first method gave, as the general effect of caffein on Squad II., retardation, except for the largest dose. The general suggestion of the present is stimulation. Since the two sets of results do not agree, we are unable to draw any conclusion whatever concerning the discrimination time for this squad. When the dose is taken in the morning, as was the case with this squad, there is thus no clear indication of any caffein influence on the discrimination reaction time. At first thought one might expect the squad averages of Tables LXXI. and LXXV. to be identical, but it must be remembered that one is the per cent. of averages, the other the average of per cents.

When the dose is taken along with lunch, as in the case of Squad III. (Table LXXVII.) the individuals do not agree. Subject 3 shows retardation from small doses and stimulation from large. The two other subjects show hardly any effect whatever from small doses, but considerable stimulation (2.5 per cent. and 4.6 per cent.)

TABLE LXXVII

DISCRIMINATION. SQUAD III., EXPERIMENT *A*

Ratio of records after dose to records before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Av. of 1 and 2 Gr. Also Difference betw. Control Av. and These	Av. of 4 and 6 Gr. Also Difference betw. Control Av. and These
3	1.016	.050	1.063	1.264	1.117	1.025	.975	1.174	.979
			1.150	1.220	1.044	.974	.945	+.158	—.037
			1.106	1.242	1.080	.999	.960		
9	1.018	.060	1.072	1.039	1.034	.981	1.009	1.016	.983
			.972	.979	.999	.994	.951	—.002	—.025
			1.022	1.009	1.016	.987	.980		
14	1.011	.028	1.013	.977	.984	1.036	.911	1.005	.965
			1.021	1.010	.986	.963	.956	—.006	—.046
			1.017	.993	.985	.999	.932		
Av.	1.015	.046	1.048	1.081	1.027	.995	.957	1.064	.976
								+.049	—.039

from larger amounts. Although the squad average shows retardation from small doses and stimulation from large, the behavior of the individuals making up the squad suggests very strongly that when the substance is taken at meal-time the retardation which is otherwise likely to be present tends to disappear.

The results for Squad IV. are thoroughly consistent with the conclusions previously drawn. The squad average shows a retardation of 3 per cent. from 1 to 4 gr. doses, and a stimulation of 4.1 per cent. from 6 gr. The individuals all conform to this rule, with the exception of the heaviest subject (No. 16, 174 lbs.) who shows stimulation from all but the 3 and 4 gr. amounts. Two of the individuals, subjects 6 and 10 (weights 125 and 157 lbs.) get stimula-

TABLE LXXVIII

DISCRIMINATION. SQUAD IV., EXPERIMENT *A*

Ratio of records after dose to records before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Av. of 1–4 Gr. Also Diff. betw. These and Control	6 Gr. Average
5	.993	.053	1.142	1.034	1.000	1.036	.959	1.053	.959
			1.007	1.063	.979	1.084	?	+.060	—.034
			1.074	1.048	.989	1.060	.959		
6	1.006	.043	1.100	1.087	1.110	1.024	.935	1.080	.976
			1.033	1.116	1.008	.917	1.018	+.074	—.030
			1.066	1.101	1.059	.970	.976		
10	1.014	.047	1.080	1.105	.953	1.012	.965	1.037	.982
			.993	1.099	1.073	1.000	.999	+.023	—.032
			1.037	1.102	1.013	1.006	.982		
11	1.006	.087	1.062	1.046	1.054	.947	.926	1.027	.934
			1.139	1.106	1.037	1.081	.943	+.021	—.072
			1.100	1.076	1.045	1.014	.934		
16	1.020	.044	.980	.907	1.020	1.080	1.019	.997	.984
			.991	.991	1.019	1.029	.950	—.023	.036
			.985	.949	1.020	1.054	.984		
Av.	1.008	.055	1.052	1.055	1.025	1.020	.967	1.038	.967
								+.030	—.041

tion from the 4 gr. dose. In the squad averages retardation is present up to the point of the 6 gr. dose, which yields stimulation. The amount of retardation, further, decreases with increase in amount of the dose, from 5.2 per cent. for 1 gr. and 5.5 per cent. for 2 gr. to 2.5 per cent. for 3 gr. and 2.0 per cent. for 4 gr., being transformed, at that point to stimulation for the 6 gr. The magnitude of the effect is again dependent on the body weight of the individuals, and is greater for subjects 5, 6 and 11 (105, 125 and 110 lbs.) than for subjects 10 and 16 (157 and 174 lbs.).

Experiment *B*

The results of Experiment *B* are given in the following curves 28–31. In this experiment special care was taken to keep the illumination of the room constant (a factor which had been somewhat variable in Experiment *A*.) All the trials were made in a room artificially lighted by using gas mantles which gave a fairly pure white light.

Squad I. (control, sugar first two days, caffein third day, dose after 6th trial) shows on control days, only a slight inclination toward inferior reactions in the latter part of the day. After the caffein dose (3 gr.) on the third day, there is possibly a slight retardation late in the evening, but this retardation, if present, is not constant, for it shows at only two or three of the trials. The final records of the day and the majority of the trials after caffein are as

Fig. 28. Discrimination Time. Experiment *B*. Squad I. (Control.)

good as those on control days. Examination of the individual records, which have been platted out in the same way as the squad averages here shown, confirms these results throughout. No individual shows any clear indication of caffein influence.

In the case of Squad II. the caffein days are marked by great irregularity, but this is present before as well as after the dose, and is due chiefly to the variable records of Subject No. 11. This irregularity renders any inference uncertain. The control day yields a fairly uniform set of records. About all that can be said of this squad is that in the trials before the dose the reactions on caffein days happen to be slower than those on the control day, during the corresponding period, but that in the evening, when all three curves settle down to uniform levels, the caffein days are in no way inferior to the control day. There is here a bare suggestion that some 3–5 hours after the dose the result of the caffein is to counterbalance the

inferiority with which the days began, bringing the initially higher caffein curves to the same level as that of the initially superior control day. That is to say, in so far as the curves show any caffein influence at all, the indications are of stimulation some 3–5 hours after the dose. Any earlier effect, if present, is obscured by the original irregularity of the records. Examination of the individual records of the subjects throws no new light on the matter.

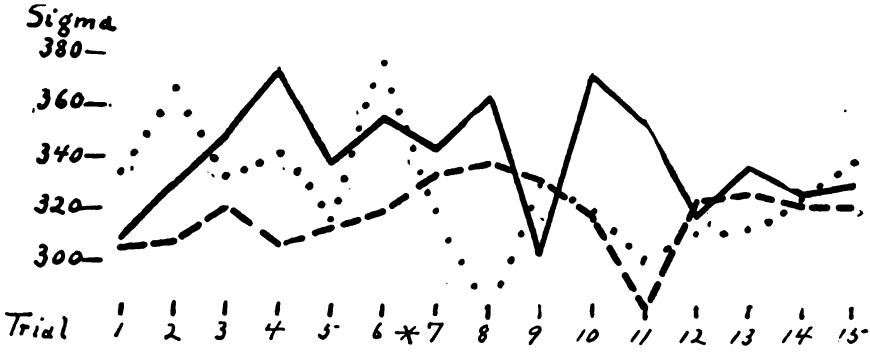


FIG. 29. DISCRIMINATION TIME. Experiment *B*. Squad II. (Solution.)

The curves for Squad III. follow a very regular course. On the first day (3 gr. caffein after 6th trial) the curve rises after the dose to a level some 20 sigma slower than that maintained before the dose, suggesting initial retardation. This effect, as it shows in the individual records, is clearly present with subjects 6, 8, 12 and 16, and is

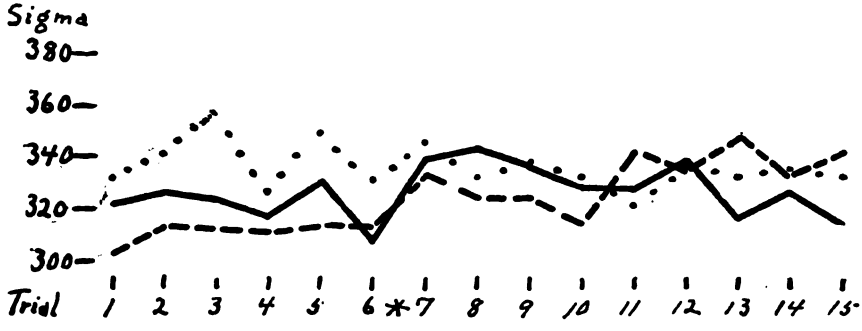


FIG. 30. DISCRIMINATION TIME. Experiment *B*. Squad III. (3 gr.)

more pronounced and persistent in the case of 6, a woman. After 4.5 hours the curve falls to a level quite equal to that of the pre-caffein period. This is true for all the individuals except Subject 6, while Subject 12 shows considerable absolute stimulation as compared with

the morning performance. On the morning after the caffein day the curve runs constantly lower than on the preceding day, until about the time of the dose. This is true for all the individuals except Subject 6 in whose case the records of the second morning are not so good. For subjects 8, 9 and 12 the superiority is considerable, averaging about 30 sigma. From this point on the curve rises gradually, showing the normal slight fatigue effect already seen in the case of Squads I. and II. This is true of the individual records of all five subjects in the squad. There is no evidence of the apparent stimulation of the preceding day after the 12th trial. These late records are the poorest of the day. On the last day (again a control day) the curve shows little change throughout its course. Except for two slow reactions during the early trials the whole curve follows a uniform level. This is true for the individual curves of all but sub-

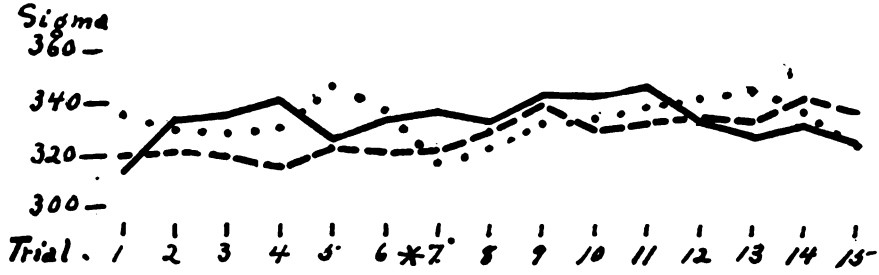


FIG. 31. DISCRIMINATION TIME. Experiment *B*. Squad IV. (6 gr.)

ject 8, in whose case the curve drops in the latter part of the day. If there is any caffein effect on this squad it is but slight, and that effect would seem to be an initial retardation followed by stimulation. There is certain evidence suggesting that this stimulation is still present on the following day. The evidence in this case is slight, however, and similar facts (the relative levels of the various morning curves) might lead one to infer retardation on the second morning after caffein, 45 hours after the dose. This result would, of course, seem quite improbable. But the persistence of caffein influence over so great an interval as 24 hours is again found in the case of Squad IV., was also suggested in the results of Experiment *A*, and was clearly found in the case of the Calculation test. There can be little doubt that it is a genuine effect.

The curves for Squad IV. resemble in every respect those of Squad III. The control curves, March 4 and 5, show the familiar slight tendency to fatigue as the day goes on. All three subjects agree in this respect. But on the caffein day the part of the curve

representing the last three hours sweeps consistently downward, as did that of Squad III. This again is true for all three subjects. As in the case of Squad III. again, this stimulation is apparently present on the following morning, the reactions there being the quickest made during the experiment. This is strikingly true with subject 14 and quite clearly so with subject 10. For the third subject, No. 3, the difference does not appear. As in the case of the third squad, the exception is the woman. If this is a genuine persistence of stimulation the low level of the curve at this time will of course have something to do with the general fatigue effect shown on this control day. The normal amount of fatigue will be overestimated somewhat and will appear more accurately on the 3d day, where it is, as a matter of fact, somewhat less conspicuous for all three subjects. There is no evidence of secondary depression following this stimulation. The subsequent trials on this second day are in no way inferior to those of the other control day. This squad took their dose (6 gr.) after the 6th trial on the first day.

The results of Experiment *B* are then thoroughly consistent with those of Experiment *A*. In the latter experiment, the retardation which was so clearly present, was produced by the smaller doses only. The initial retardation after 3 gr. doses was very slight. After 6 gr. doses there is no indication of retardation whatever, but on the contrary a very slight tendency to stimulation or else no effect whatever. When the stimulation was present it was found persisting on the following day, as was the retardation from the 1 and 2 gr. doses.

Experiment *C*

The records for Experiment *C* are given in Table LXXIX. In this experiment the dose was given in syrup form, only 15 minutes before the trial. But Experiments *A* and *B* agree in showing no effect on the discrimination reaction time until several hours after the dose. Quite in harmony with this result is the fact that in Experiment *C* there is no clear difference shown between the three types of days, the blank days, the plain syrup days and the caffeinated syrup days. The table presents the results for each subject, the figure meaning in each case the ratio between the average performance after the dose to the average performance before the dose. The table also gives the squad averages for each day, as well as for the various types of day. There is evidence of a very slight amount of sensory stimulation (not over 1 per cent.), and in this respect the caffein days differ not at all from the plain syrup days. As has already been pointed out in the case of some of the other tests, sen-

sory stimulation affects motor performance much more than mental performance, and since the caffein effect on mental performance is also slower than that on motor processes, Experiment *C* fails to yield any result whatever.

With the idea of investigating the effect of caffein on the accuracy and constancy of the process of discrimination involved in this test, record was kept of the number of false reactions on the part of each subject—reactions on the "blue key" when the stimulus turned

TABLE LXXIX

DISCRIMINATION. EXPERIMENT *C*

Giving for each subject the ratio of the average performance after the dose to the average performance before the dose. Over 100 means fatigue

Subject	1	3	4	7	8	9	10	11	12	13	14	15	Average
Blank	103.1	94.8	101.2	104.2	99.1	95.4	98.4	98.2	94.9	94.9	98.7	102.8	98.8
days	101.2	100.8	105.7	116.7	107.9	102.5	98.6	103.8	absent	100.7	104.4	87.7	102.7
												Av.	100.7
Syrup	107.9	102.4	98.2	88.7	107.8	103.3	92.1	100.5	100.9	96.9	91.4	93.2	98.5
days	98.1	96.2	101.6	96.1	107.1	102.8	95.8	94.0	110.7	110.7	102.1	95.9	100.5
												Av.	99.5
1.2 gr. caf.	96.6	95.3	102.3	100.9	93.6	98.3	98.0	94.4	87.3	92.1	104.0	94.8	96.4
3.6 gr. caf.	114.7	101.2	109.1	103.0	101.7	95.1	100.3	80.6	100.5	100.6	100.9	123.7	103.0
6 gr. caf.	101.5	98.0	97.7	87.9	97.7	103.3	98.3	97.0	absent	94.4	106.3	102.9	98.7
												Av.	99.4

out to be really red and reactions on the "red key" to the blue stimulus. Table LXXX. gives a summary of these records in Experiment *A*. The number of false reactions was very small in the case of all the subjects. The table gives the total number of false reactions during the trials before the dose and the total number during the trials after the dose, for each subject, on both control and caffein days, with no attempt to separate the data according to the size of the dose, because of the small number of false reactions during the month. The table gives also the ratio of false reactions after the dose to the number before the dose, for both sugar and caffein. The squad records are also computed, using the total number of false reactions made by the squad, instead of the average. Squad I. shows no difference between the real control days and the pseudo-caffein days. The average ratio of errors after the dose to errors before the dose being 63 per cent. on one type of day and 62 per cent. on the other. In the case of Squad II. (dose in forenoon) the caffein days are for all three subjects superior (after the dose) to the control days. It will be recalled that by one method of com-

TABLE LXXX

DISCRIMINATION. EXPERIMENT *A*

Giving the total number of false reactions made by each subject during Experiment *A*. In the first column under a given type of day are given the total number of false reactions in the trials preceding the dose. In the second column occur the total number in the trials after the dose, for both control and caffein days. In the third column is given the ratio of the number of false reactions after the dose to that before. The subjects are assembled by squads according to character and time of the dose.

	Control Days			Caffein Days		
Subject	Before	After	Per Cent.	Before	After	Per Cent.
1	9	7	67.7	16	8	50.0
4	14	7	50.0	11	7	63.5
7	16	15	93.5	15	7	46.6
15	8	1	12.5	5	7	140.0
Squad I.—Total	47	30	63.0	47	29	62.0
8	9	21	231.0	14	10	71.4
12	17	35	203.0	16	26	162.0
13	15	19	126.5	19	24	126.0
Squad II.—Total	41	75	183.0	49	60	122.0
3	21	7	33.3	17	17	100.0
9	17	13	76.5	22	9	41.0
14	33	11	33.3	24	17	70.6
Squad III.—Total	71	31	44.0	63	53	84.0
5	10	6	60.0	14	9	64.0
6	16	4	25.0	6	3	50.0
10	17	7	41.2	16	11	68.7
11	31	21	67.7	33	28	85.0
16	23	13	56.5	27	15	55.7
Squad IV.—Total	97	51	53.0	96	66	69.0

putation this squad showed retardation for small doses and stimulation for large, while by another method it showed stimulation for all doses at the earlier periods and retardation at a later period for medium doses only, the small and large amounts appearing to produce stimulation. Our conclusion was that no consistent effect could be made out on this squad. It is at least clear that the caffein did not produce increased number of errors. Squad III., on the other hand, showed, by both methods of computation, retardation for small doses. And here the number of mistakes on the caffein days (after the dose) is seen to be greater by 40 per cent. than the number made on control days. Squad IV., with similar caffein effect from the point of view of time, shows a caffein inferiority of 16 per cent. Only one subject out of the eight in these two squads is an exception to this rule.

Table LXXXI. shows the number of false reactions at each trial on each of the three intensive days of Experiment *B*. The upper part of the table gives the total number of false reactions made at each of the 15 trials by the 10 subjects comprising the various caffein squads. The lower part gives similar figures for the control squad. This table gives a good measure of the accuracy with which these discriminations were made, indicating the complete absence of guesses in the reactions. Out of a total of between 8,575 and 11,700 reactions there were only 390 false reactions, about 4 out of every 100. But caffein seems to have had no influence whatever on the number of these false reactions. Whether the records after the dose are compared with those before the dose, or whether the caffein days are compared with control days, no difference whatever is found.

TABLE LXXXI

FALSE REACTIONS. EXPERIMENT *B*

The upper part of the table gives the total number of false reactions made by members of the caffein squads, and the lower part those by the control squad, at each trial on each of the three days. Dose after the sixth trial.

Caffein squad 10 subjects; 150 to 200 reactions at each trial

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mar. 3	18	12	8	6	4	9	12	8	6	6	6	11	7	10	5
Mar. 4	7	6	10	4	4	7	9	13	6	6	7	5	7	11	9
Mar. 5	7	10	8	4	7	4	8	5	9	4	9	5	6	7	8

Control squad 8 subjects; 45 to 60 reactions at each trial

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mar. 3	0	2	1	0	1	2	1	2	2	2	1	1	1	0	0
Mar. 4	0	4	0	2	0	1	0	2	8	0	0	1	0	0	0
Mar. 5	0	2	3	0	2	1	2	1	0	1	1	1	2	1	0

The significance of these facts is at once apparent. In Experiment *A* the squads showing retardation showed also a greater per cent. of false reactions. The squad showing no such retardation clearly, showed no such increase in false reactions, but rather a decrease. In Experiment *B*, in which there is no clear evidence of retardation the number of false reactions is found to be unaffected. To those familiar with the conditions of the discrimination reaction experiment, or to any one observing the behavior of subjects under the influence of caffein at such a test, it will at once occur that the retardation found in the discrimination times is in all probability an effect of stimulation. In such a test stimulation is likely to lead to a fatal briskness in the first few reactions in a series, resulting in false reactions and in a subsequent voluntary caution as a measure designed to counteract these false reactions. Such an effect would

appear in the records as a retardation in discrimination time. The retardation consequent upon small doses and the stimulation produced by larger amounts, in this test, does not then point to any complexity in the character of the caffein action. It seems much more likely that the effect is really stimulation for all doses, the amount perhaps increasing with the size of the dose. In the case of large amounts in the present experiment the great amount of stimulation produced combined with the fact that by the time these doses were given the subjects had had almost a month's practise in the

TABLE LXXXII

VARIABILITY. EXPERIMENT *B*

Giving the average variability of the individuals from their own average in the 10 reactions of a given sitting. The table gives the squad averages for each trial on each of the three days. These M.V.'s are seen to be about 10 per cent. of the discrimination time. Dose after the sixth trial. Trials given consecutively from 1 to 15.

						Squad I									
Mar. 3	26	37	44	40	38	32	33	39	28	44	44	34	37	47	38
Mar. 4	30	30	53	36	49	39	40	33	46	59	45	48	53	39	40
Mar. 5	32	39	40	52	44	47	52	46	40	57	40	52	50	40	38
						Squad II									
Mar. 3	29	36	51	38	42	37	50	38	29	33	46	34	58	42	47
Mar. 4	48	35	35	44	40	52	52	73	50	54	49	32	60	36	46
Mar. 5	36	42	24	41	60	64	45	51	43	66	34	46	54	41	29
						Squad III									
Mar. 3	22	27	28	27	32	27	28	36	33	37	33	24	35	36	32
Mar. 4	28	40	31	34	34	37	40	30	41	37	42	43	37	46	42
Mar. 5	34	42	38	32	45	38	33	43	39	38	36	48	36	31	29
						Squad IV									
Mar. 3	20	17	24	35	39	33	42	24	39	41	36	25	29	29	34
Mar. 4	34	33	26	31	28	27	29	33	31	32	23	27	53	29	28
Mar. 5	32	32	36	33	50	28	36	27	39	35	33	32	30	37	25

test really led to accelerated reaction times. A similar explanation no doubt is at the bottom of the retardation produced by large doses in the case of the three-hole (coordination) test and the typewriting test.

Up to this point nothing has been said of the variabilities of these discrimination times. It has not seemed worth while to give these variabilities in full, because of the large amount of space that would be required. But in order to give some notion of their magnitude Table LXXXII. has been compiled. Each record in this table is the average of the M.V.'s of all the subjects in a given squad at a

stated test. The 10 trials on the part of each individual were averaged. The M.V. of this individual average was computed. This was done for each individual in the squad. The average of these personal M.V.'s, at each test on each of the three intensive days, is the record to be found in Table LXXXII. Since the discrimination times range between 300 sigma and 400 sigma, the M.V.'s are in the long run about 10 per cent. of the discrimination time. This per cent. will serve as an approximate statement of the variability of the averages discussed in the preceding paragraphs of this chapter. The variability does not seem to be in any way influenced by the caffein doses. The general tendency is for the variability to increase somewhat as the day goes on, but this tendency is not always present, nor is it found with all individuals, though it shows up fairly well in the averages. This increase begins at about the time of the 6th trial, after which the dose was always taken. But the caffein days and control days show no clear difference either in the amount or in the time of appearance of this increase.

Summary

Small amounts of caffein tend to produce retardation in discrimination time, this retardation being accompanied by a greater number of false reactions. The false reactions appear to be caused by a preliminary briskness produced by the caffein, and the retardation in reaction time caused by a voluntary caution in the attempt to eliminate the false reactions. This is a test in which stimulation does not make for efficiency except after long practise. Larger amounts of caffein produce within 2 hours after the dose a stimulation so great that the retardation following small doses does not appear. Greater familiarity with the test may also contribute to this effect. The caffein effect seems very persistent in this test, and traces of it are found on the following day. When retardation is present it does not appear until very late, whereas the stimulation comes quickly. This again appears to be due to the size of the dose, the larger amounts acting more quickly. The caffein does not seem to modify the variabilities of the reaction times. When the dose is taken in the morning no effect can be consistently made out. When it is taken along with the mid-day meal the retardation for small doses tends to disappear. The magnitude of the caffein influence varies inversely with body weight, as in most of the other tests.

CHAPTER XII

The Influence of Caffein on the Cancellation Test

One unsatisfactory feature of the use of simple tests is the fact that it is not always apparent what function or set of functions, what process, faculty or capacity is being measured. Thus the cancellation test has been used by various investigators for the measurement of such varying factors as "degree of attention," "discrimination," "rate of perception," "fatigue," "capacity to break and form associations," "distraction," etc. One would suppose that certain of the numerous tests devised for experimental purposes would be more or less closely related to each other; not necessarily to the degree of assuming particular "faculties" involved in their performance, but at least to the degree that similar nervous mechanisms might be employed. Such tests would theoretically correlate with each other from the point of view of individual proficiency. But the method of correlating proficiencies has so far failed to afford a reliable classification of the various tests. The difficulty perhaps arises from the fact that relative performance in specific tests is largely conditioned by unequal and more or less particularized skill, interests, familiarity and adaptation with respect to operations somewhat analogous to those involved in certain of the tests. Consequently correlations in performance would not reflect qualitative resemblances and differences in the tests, but rather the presence or absence of these various sorts of specialization. As an illustration, the cancellation test might involve the same functions as the color discrimination reaction test, and yet the two tests not correlate to any marked degree in a given individual because of specialized skill in proof reading, or because of individual differences in the method of performing the test.

Conceivably similarity of function or of nervous mechanism involved might be determined by comparing the qualitative or quantitative effect, on the two tests, of an influence which is more or less specialized and localizable in its action on nervous process, such an influence as that of a drug with nervous action. The application of this criterion the writer believes to be possible. Such application seems to throw new light on the character of the hitherto vaguely classified cancellation test.

This test was one of the three which were omitted in the three-

TABLE LXXXIII

CANCELLATION TEST. SQUAD I., EXPERIMENT *A*. DAILY AVERAGES

	February																		
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
7:45	95.6	94.4	96.1	97.7	95.3	93.4	88.7	92.5	90.5	90.5	95.5	88.8	97.3	96.1	97.4	90.3	83.8	83.7	90.7
10:00	94.5	83.5	90.2	95.9	87.9	92.3	93.7	95.3	92.4	100.9	88.7	94.7	93.9	89.1	93.0	91.9	90.1	86.5	90.5
12:00	97.3	101.2	99.1	100.5	102.5	99.2	96.3	96.3	97.4	92.9	91.5	97.6	90.7	83.9	90.7	89.2	81.4	88.9	89.2
1:00	Dose, sugar capsules only, daily at 1:00 P.M.																		
3:10	108.3	105.7	103.2	116.9	107.5	117.4	104.7	110.9	110.5	115.1	111.3	106.3	105.9	105.2	99.5	97.3	102.7	98.7	104.0
5:30	95.1	96.9	97.1	93.8	95.8	91.8	91.8	91.8	87.2	85.3	90.3	89.6	85.9	92.9	90.3	81.6	84.2	88.9	85.0

TABLE LXXXIV

CANCELLATION TEST. SQUAD II., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	101.8	98.6	*91.7*	*94.7*	*98.6*	90.2	87.1	*96.5*	*89.9*	*89.2*	92.3	84.3	86.6	*87.3*	*78.3*	*83.7*	81.6	79.8	81.9	*79.4*	75.5
10:00	98.9	101.3	*102.2*	*100.8*	*101.9*	94.3	95.7	*97.9*	*99.4*	*98.1*	89.1	100.9	84.0	*94.9*	*88.5*	*84.4*	91.9	83.2	82.7	*89.5*	79.3
10:30	S	S	*1 gr.*	*1 gr.*	*1 gr.*	S	S	*2 gr.*	*2 gr.*	*2 gr.*	S	S	S	*4 gr.*	*4 gr.*	*4 gr.*	S	S	S	*6 gr.*	S
12:00	96.4	98.7	*93.0*	*91.9*	*91.1*	91.5	91.7	*82.7*	*86.2*	*84.3*	88.2	81.7	88.5	*79.1*	*82.7*	*80.7*	86.3	78.9	80.3	*80.2*	83.8
3:10	116.5	103.3	*109.3*	*99.9*	*110.5*	109.7	108.9	*101.1*	*101.9*	*101.2*	98.9	97.9	104.3	*101.4*	*88.5*	*96.7*	97.3	94.6	95.8	*91.6*	94.8
5:30	100.1	99.3	*102.3*	*98.0*	*90.5*	84.9	86.0	*82.1*	*82.3*	*81.7*	82.3	78.1	78.9	*75.3*	*73.4*	*76.6*	79.6	74.1	78.4	*70.2*	73.5

TABLE LXXXV

CANCELLATION TEST. SQUAD III., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	114.0	*106.5*	103.0	*96.1*	94.8	*88.4*	96.5	*86.8*	100.9	*87.2*	85.1	*87.6*	92.6	*94.9*	84.2	*81.8*	86.1	*92.0*	88.2	*83.1*	80.7
10:00	93.3	*86.0*	102.6	*83.4*	88.5	*94.7*	90.2	*94.1*	94.9	*95.1*	85.0	*87.8*	81.5	*82.1*	83.9	*75.0*	82.0	*79.9*	80.9	*81.6*	78.8
12:00	92.9	*89.5*	89.8	*100.4*	84.4	*90.1*	92.9	*92.9*	92.9	*99.1*	87.3	*89.9*	84.0	*85.6*	89.2	*86.6*	79.0	*83.6*	81.0	*84.2*	82.5
1:00	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	110.0	*109.4*	109.1	*111.5*	112.5	*119.0*	113.5	*113.3*	100.7	*102.0*	94.2	*100.9*	101.1	*87.1*	102.6	*91.6*	87.6	*94.0*	97.2	*91.1*	90.3
5:30	89.7	*86.6*	88.5	*78.5*	83.9	*81.3*	89.5	*90.8*	77.9	*75.1*	77.9	*72.3*	74.0	*77.5*	80.3	*76.2*	77.6	*70.9*	76.0	*74.8*	78.1

TABLE LXXXVI

CANCELLATION TEST. SQUAD IV., EXPERIMENT *A*

	February																		March	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2
7:45	110.6	*103.5*	101.3	*100.2*	99.2	*92.5*	101.9	*96.4*	93.8	*95.5*	99.0	*88.7*	89.6	*85.5*	84.3	*89.1*	83.0	*92.0*	87.0	*91.2*	95.4
10:00	102.2	*99.8*	97.1	*95.4*	99.4	*98.6*	96.9	*91.3*	96.7	*93.3*	94.5	*90.4*	88.6	*86.4*	84.9	*86.6*	80.3	*88.4*	88.7	*91.3*	93.3
12:00	98.2	*93.5*	92.3	*93.7*	95.4	*92.5*	97.5	*96.5*	94.3	*97.3*	90.0	*87.7*	88.4	*86.6*	88.0	*91.0*	79.2	*92.4*	85.6	*82.0*	81.7
1:45	S	*1 gr.*	S	*1 gr.*	S	*2 gr.*	S	*2 gr.*	S	*3 gr.*	S	*3 gr.*	S	*4 gr.*	S	*4 gr.*	S	*6 gr.*	S	*6 gr.*	S
3:10	124.1	*106.5*	112.4	*114.0*	112.0	*119.3*	112.8	*111.3*	108.0	*113.7*	105.7	*105.9*	113.0	*110.7*	104.9	*105.0*	103.3	*99.4*	96.5	*99.4*	101.9
5:30	94.6	*89.6*	96.0	*94.1*	101.4	*89.6*	90.6	*86.4*	86.1	*87.6*	86.1	*91.0*	86.8	*81.6*	92.9	*83.0*	82.2	*83.7*	83.8	*85.2*	84.2

day intensive experiment (*B*) and in the seven-day experiment with syrups (*C*). Hence the only records available are those secured in Experiment *A*. The test is an unsatisfactory one to use, in the first place because of the impossibility of maintaining uniform illumination except by artificial means. This provision was not adequately controlled in Experiment *A*. In the second place, since different characters were cancelled (2, 3, 5, 6, 8) at each of the five tests on a given day and since these characters differ among themselves in perceptibility, the successive trials on a given day can not satisfactorily be compared with each other. The comparison of similar tests on different days is not influenced by differences in the character cancelled, but such comparisons, under only roughly controlled conditions of illumination are uncertain in value. The individual curves are for the most part very irregular and the squad records are correspondingly so. The conclusions as to the influence of caffein on the cancellation test are consequently given with considerable reservation.

Tables LXXXVII.–LIX. give the comparison of actual with calculated records for Squads I., III. and IV. Table LXXXVIII. gives the averages for each trial on each type of day, for Squad II., the average of the two trials before the dose being adopted as the standard for the day and the ratios for the later trials referring to this standard.

At the 3:10 test the control squad (I.) shows a tendency to be slow in pseudo-caffein days. Squad III. shows the same tendency except for the larger doses, which yield stimulation. Squad IV. gives balanced records, differing from the control squad only in the absence of retardation. At the 5:30 test the control squad yields records which balance. Squad III. shows a small amount of stimulation, as does Squad IV. for the smaller doses. On the post-caffein days (morning records) the control squad yields balanced records at all hours. Squad III. at the 7:45 and Squad IV. at all three morning trials suggest retardation after the small and continued stimulation after the large doses of the preceding caffein days.

Squad II. (Table LXXXVIII.) after 1 gr. yields records not distinguishable from those of the control days. But after 2, 4 and 6 gr. all the subsequent trials show stimulation, which is larger at the 12:00 test for the 2 gr. dose, but greatest for the 6 gr. amount at the later 5:30 trial. The average per cent. stimulation is greatest in the case of the 2 gr. dose.

In Tables XCI.–XCII. the records for this Squad II. are again computed, the individuals being treated separately, the 12:00 and 3:10 trials being averaged for one table and the 5:30 trial being

TABLE LXXXVII

CANCELLATION. SQUAD I., EXPERIMENT *A*

Sug. Av.	7:45 Caf. Av.	Dif.	Sug. Av.	10:00 Caf. Av.	Dif.	Sug. Av.	12:00 Caf. Av.	Dif.	1:00 Dose	Sug. Av.	3:10 Caf. Av.	Dif.	Sug? Av.	5:20 Caf. Av.	Dif.
95.8	96.0	— 0.2	90.7	89.7	+ 1.0	99.5	100.9	— 1.4	S	105.6	111.3	— 5.7	96.3	95.4	— 0.9
90.8	93.0	— 2.2	91.9	93.8	— 1.9	99.1	97.8	+ 1.3	S	106.4	114.3	— 7.9	91.7	91.8	+ 0.1
94.7	89.6	+ 5.1	90.9	97.8	— 6.9	92.6	94.7	— 2.1	S	109.8	110.7	— 0.9	88.4	87.4	— 1.0
94.2	93.2	+ 1.0	92.5	90.5	+ 2.0	88.4	86.5	+ 1.9	S	101.9	101.2	+ 0.7	87.7	87.3	— 0.4

TABLE LXXXVIII

CANCELLATION. SQUAD II., EXPERIMENT *A*

Dose	Av. 1st and 2d Trials	3d Trial	4th Trial	5th Trial	Av. 3, 4 and 5
Sugar Av.	91.4	89.2	103.8	86.0	
Per cent. of Av.	100.0	97.7	113.4	94.3	101.8
1 gr. caffein	95.7	94.8	110.4	90.1	
Per cent. of Av.	100.0	99.0	115.0	94.0	102.6
2 gr. caffein	95.0	84.1	101.4	82.0	
Per cent. of Av.	100.0	88.3	106.7	86.3	93.7
4 gr. caffein	86.0	80.8	95.5	75.1	
Per cent. of Av.	100.0	94.0	111.0	87.2	97.4
6 gr. caffein	84.5	80.2	91.6	70.2	
Per cent. of Av.	100.0	95.0	107.3	83.0	95.1

TABLE LXXXIX

CANCELLATION. SQUAD III., EXPERIMENT *A*

	7:45			10:00			12:00			3:10			5:30	
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.	1:00 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
103.7	101.3	+ 2.4	96.5	84.7	+11.8	88.7	95.0	— 6.3	1 gr.	110.2	110.4	— 0.2	87.7	82.5	+ 5.2
97.2	87.6	+ 9.6	90.9	94.4	— 3.5	90.8	91.5	— 0.7	2 gr.	109.8	116.1	— 6.3	85.2	86.0	— 0.8
90.4	87.4	+ 3.0	86.6	91.4	— 4.8	87.9	94.5	— 6.6	3 gr.	97.6	101.4	— 3.8	77.0	73.7	+ 4.0
86.8	88.3	— 1.5	82.8	78.5	+ 4.3	85.4	86.1	— 0.7	4 gr.	98.5	89.4	+ 9.1	78.1	76.9	+ 1.2
85.8	87.6	— 1.8	80.6	80.8	— 0.2	80.8	83.9	— 3.1	6 gr.	93.1	92.5	+ 2.4	76.9	72.4	+ 4.5

TABLE XC

CANCELLATION. SQUAD IV., EXPERIMENT *A*

	7:45			10:00			12:00			3:10			5:30	
Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av	Dif.	Sug. Av.	Caf. Av.	Dif.	1:45 Dose	Sug. Av.	Caf. Av.	Dif.	Sug. Av.	Caf. Av.	Dif.
103.1	101.8	+ 1.3	98.9	97.6	+ 1.3	94.7	93.1	+ 1.6	1 gr.	110.2	110.2	0.0	97.0	91.9	+ 5.1
99.2	94.5	+ 4.7	97.5	94.9	+ 2.6	96.2	94.5	+ 1.7	2 gr.	111.4	115.3	— 3.9	92.2	88.0	+ 4.2
95.4	92.1	+ 3.3	93.6	92.9	+ 0.7	100.7	92.5	+ 8.2	3 gr.	108.1	108.8	— 0.7	86.3	89.3	— 3.0
85.3	87.8	— 2.5	84.7	86.5	— 1.8	85.9	88.8	— 2.9	4 gr.	106.5	107.8	— 1.3	86.2	82.3	+ 3.9
88.1	91.6	— 3.5	87.6	89.9	— 2.3	83.0	87.2	— 4.2	6 gr.	99.6	99.4	+ 0.2	83.5	84.4	— 0.9

presented separately. The ratios are presented for each individual, and the squad average in these tables is therefore not the ratio of the average record of the squad but the average of the ratios of the three individuals. Hence the ratios do not completely correspond to those given in Table LXXXVIII.

The ratios in Table XCI. can not be compared directly with those in Table XCII., since at these various trials different digits were cancelled and the difference between the two tables is chiefly a func-

TABLE XCI

CANCELLATION. SQUAD II. EXPERIMENT *A*

Ratio of 12:00 and 3:10 trials (average) to trials before dose (av.)

Subj.	Control Average	M.V.	1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.
8	1.078	.071	.965	.043	1.036	.073	1.039	.030	1.075
12	1.101	.057	1.144	.053	1.052	.066	1.093	.126	1.023
13	1.019	.047	.933	.077	.900	.063	.945	.027	.958
Av.	1.066	.058	1.014	.058	.996	.067	1.026	.061	1.018

TABLE XCII

CANCELLATION. SQUAD II. EXPERIMENT *A*

Ratios of 5:30 trials to trials before dose (av.)

Subj.	Control Average	M.V.	1 Gr.	M.V.	2 Gr.	M.V.	4 Gr.	M.V.	6 Gr.
8	.783	.048	.817	.040	.765	.063	.750	.030	.705
12	1.081	.039	1.130	.020	1.020	.036	1.001	.103	.955
13	.978	.065	1.036	.120	.854	.050	.906	.033	.882
Av.	.947	.051	.994	.060	.879	.049	.886	.055	.847

tion of the difference in the relative ease of marking out these different characters. But within any one table the control days may be compared with the caffein days. If this is done all doses of caffein are seen to have produced stimulation at the 12:00 and 3:10 tests (dose at 10:30), only one of the caffein ratios (subject 12 for 1 gr.) being larger than the corresponding control ratio. But by the time of the 5:30 test this 1 gr. dose has produced retardation with all three subjects, the average amount being almost 5 per cent. All larger doses yield stimulation for all three subjects. On the basis of these tables combined with the evidence from Table LXXXVIII., the caffein effect on Squad II. is clearly a general tendency toward stimulation, except for the small doses, which produce records inferior to those of control days.

When the records for Squads I., III. and IV. are treated by this ratio method, the ratios of each subject being computed separately and the squad record consisting of the average of these ratios,

Tables XCIII. to XCV. result. The control squad (Table XCIII.) shows slightly inferior records on the pseudo-caffein days (about 2 per cent.). There are but three subjects in this squad for this test, subject 1 having been unable to complete the test on account of eyestrain. Of these three subjects two are better on control days and one on pseudo-caffein days.

In the case of Squad III. (Table XCIV.) all three subjects show retardation after the small doses (1 and 2 gr.) and stimulation after larger amounts. In the squad average this effect shows up clearly, the retardation from 1 and 2 gr. averaging 4.5 per cent. and the stimulation from larger amounts averaging 5.6 per cent. This squad thus quite confirms the conclusions based on the records of Squad II.

TABLE XCIII

CANCELLATION. SQUAD I., EXPERIMENT *A*

Ratios of performance after dose to performance before dose

Subj.	Control Av.	M.V.	Pseudo-Caf. Av.	M.V.
1	Test omitted because of eyestrain.			
4	1.061	.023	1.077	.047
7	1.096	.057	1.085	.061
15	1.021	.027	1.079	.067
Average	1.059	.036	1.080	.058

TABLE XCIV

CANCELLATION. SQUAD III., EXPERIMENT *A*

Ratios of performance after dose to performance before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	3 Gr.	4 Gr.	6 Gr.	Av. of 1 and 2 Gr. Also Differences betw. These and Control Av.	Av. of 3 to 6 Gr.
3	.961	.071	1.043	.993	.885	.852	.823		
			.910	.942	.908	.966	.963	.972	.899
			.976	.967	.896	.909	.893	+.011	—.062
9	1.099	.051	1.010	1.170	1.046	1.068	1.093		
			1.103	1.260	1.020	1.070	1.060	1.137	1.059
			1.056	1.218	1.033	1.069	1.076	+.036	—.040
14	1.029	.062	1.080	1.120	.888	.905	.990		
			1.040	1.220	.950	1.072	.972	1.115	.963
			1.060	1.170	.919	.988	.981	+.086	—.048
Av.	1.029	.061	1.030	1.118	.949	.988	.983	1.074	.973
Difference between caffein and control averages								+.045	—.056

In the case of Squad IV., taking the dose in mid-afternoon the retardation runs higher up along the scale of doses, and the five

subjects do not agree among themselves. No. 5 is retarded by all but the 2 and 3 gr. amounts, these giving stimulation. In the case of No. 6 it is just these two amounts that yield retardation, other doses producing apparent stimulation. Subjects 10, 11 and 16 show no uniform tendency except that all are stimulated by the 6 gr. amount.

TABLE XCV

CANCELLATION. SQUAD IV., EXPERIMENT *A*

Ratios of performance after dose to performance before dose

Subj.	Control Average	M.V.	1 Gr.	2 Gr.	3 Gr.	4 Gr.	Av. of 1 to 4 Gr. Also Difference Between These and Control Ave.	6 Gr.
			1.035	1.055	1.075	1.190		1.050
			1.160	1.020	1.017	1.117		1.180
5	1.085	.070	1.097	1.037	1.046	1.153	1.083	1.115
							—.002	+.030
			1.050	1.072	1.030	1.059		.915
			.977	1.000	1.130	.943		.970
6	1.021	.077	1.013	1.036	1.080	1.001	1.032	.942
							+.011	—.079
			1.225	1.100	1.025	1.100		1.052
			1.050	.995	1.150	1.093		1.080
10	1.093	.057	1.137	1.047	1.082	1.096	1.090	1.066
							—.003	—.027
			.853	1.030	1.015	1.034		.956
			1.053	1.025	1.000	1.047		.950
11	1.037	.095	.953	1.027	1.007	1.040	1.007	.953
							—.030	—.084
			1.061	1.270	1.150	1.200		1.050
			1.161	1.222	1.285	1.108		1.110
16	1.131	.086	1.111	1.246	1.217	1.154	1.182	1.080
							+.051	—.051
Av.	1.073	.077	1.060	1.078	1.086	1.088	1.078	1.031
							+.005	—.042

In the squad averages this situation leads to the same result as that found with the other two squads. Up to 4 gr. there is very slight retardation (the average amount being .5 per cent), while the large dose yields 4.2 per cent. stimulation.

The general tendency must be said to be stimulation, except for small doses, and for larger doses in the case of some subjects. In the introspective reports of the subjects it is quite generally stated

that difficulty in this test arose from the tendency to skip digits and from the consequent necessity of going back and hunting for them (there were five digits in each line and the assistant called out each time a digit in a line had been omitted, the subject being required to mark out all digits before his record was complete). It looks as though the retardation might have come from a real stimulation and a consequent briskness which led to omissions in the attempt to do the test quickly.

It appears further that individual differences in this test and in the character of the caffein effect may depend largely on individual ways of performing the task. With some subjects the test seems to involve simply a recognition process, without any considerable amount of discrimination. Thus subject 12 says of this test, "In the course of the experiment I tried to allow my eye to run along in advance of my pencil, without identifying any number except those I wanted to cancel." After the first 4 days of the caffein weeks this subject shows no retardation. No. 14 also says, "As the experiment progressed I tried to make the eye take in about one third of a line at a time and do it rapidly, just trusting that somehow I would not overlook one." After the first few days of the experiment this subject got an average stimulation of 5 per cent. from the caffein doses. Subject 9, on the other hand, writes, "At the beginning of the experiment the figures which I was cancelling seemed to stand out from the rest. This, after a few days, disappeared and I had to scan every figure in order to get all of those on which I was working." This subject's record shows that during the first part of the experiment, in which the simple method of recognition seems to have been followed, the caffein (1 gr.) produced a stimulation of 4.3 per cent. But from that point on the 2 gr. amounts produced retardation and after the 3, 4 and 6 gr. doses the ratio of the 1 gr. was never equalled. That is to say, in some cases this cancellation test seems to be carried on in terms of simple recognition, direct perception and motor response, with little discrimination involved. In other cases it seems necessary to perform a real act of discrimination in which the correct figure is not merely recognized in itself but more or less explicitly distinguished from the others. In the former case the caffein influence tends to be stimulation without any interference. In the latter case the test resembles the discrimination-reaction experiment, and during the early part of the experiment the effect of the caffein is disastrous because the briskness of performance results in omissions and consequent delay in recovery.

Comparison of these results with the character of the caffein influence in the case of the other tests is interesting from the point of

view of the attempt at qualitative classification suggested in an earlier paragraph. In the case of the tapping test there was stimulation also, but this effect came quickly and increased directly with the size of the dose. In the coordination and typewriting tests small amounts produced stimulation but large amounts retardation. Calculation, opposites and color-naming showed stimulation for the total range of doses. Discrimination time was retarded by small and quickened by large amounts. The cancellation test does not clearly resemble any of these groups. On the basis of the squad averages and of some of the individual records it resembles the discrimination time test. But some of the subjects get effects much more similar to those produced on tests involving processes of direct recognition and simple association. These results show the cancellation test to be just such an indefinite and borderline test as the earlier description of it implied. The process measured by it will vary with the individual and at different times in the history of the same individual's performance. Attempts to correlate proficiency in the cancellation tests with other sorts of ability have usually resulted in very low correlation. This may perhaps be partially explained by the indication that the test does not measure the same process, function or capacity under different circumstances or with different individuals.

Summary

The caffein influence on the cancellation test does not usually show itself until several hours after the dose. Perhaps as a result of this tardiness the effect seems to be greater in the case of the squad taking the dose in the morning. The general effect is stimulation for large doses, but small doses show retardation in the squad averages, while some individuals get retardation for larger amounts. The results are influenced considerably by individual differences in the method of performance. When the test seems to proceed in terms of simple recognition of the figure to be cancelled, the result is stimulation, as in the tests of association processes and speed of movement. But when it is necessary to examine each figure on the sheet, discriminating in a rather explicit way the correct from the false characters, the test comes to resemble the discrimination reaction in character and in the nature of the caffein influence. In the absence of intensive tests nothing can be said concerning the persistence time of this influence and nothing with assurance concerning its after effect. There is a bare indication of continued retardation in the records on mornings after caffein days on which small doses were given. The results do not recommend the test for purposes similar to those of the present investigation.

CHAPTER XIII

The Influence of Caffein on Sleep[1]

Throughout the experiment each subject kept daily records of his general condition of health and spirits throughout the day, indicating in his special "Daily Health Book" any signs of bodily distress or discomfort, such special or general organic, digestive and nervous disturbances as might be noted from time to time, and in general as good an introspective account as possible of his mood and tonus. In addition to stating the character of any symptoms or unusual observations, the time of their appearance and their duration was noted and reference made to any outside factor which might have been responsible for the condition described. This health record was divided into two parts, the first having to do with the day-time hours preceding the evening on which the entry was made, and the second having to do with the night-hours following. This second entry was made on the following morning, immediately on arrival at the laboratory. At this time each individual recorded the approximate number of hours which he had slept during the night and described the quality of his sleep as "better than usual," "ordinary," or "worse than usual." In working up these data the approximate number of hours was accepted as stated. From the point of view of character or quality an attempt was also made to express the effect of caffein in numerical form. Representing the individual's *usual* quality of sleep by a value of 2, letting the value 1 indicate sleep which according to the judgment of the individual himself was *better than usual,* and letting the value 3 represent the quality of sleep which the individual himself judged to be *worse than usual,* tables were compiled from the introspective records occurring in the daily health books. In the individual averages then as well as in the squad averages, a value of 2.00 indicates normal sleep, all values less than 2.00 indicate sleep judged unusually good while all values larger than 2.00 indicate impaired sleep.

It will be recognized at once that these measures of sleep quality are only rough and approximate, but it is just as obvious that they are as accurate measurements of the thing in question as can well be secured. The individual himself is the only one who knows any-

[1] Reprinted from *American Journal of Psychology,* January, 1912.

thing about his customary sleep quality. In daily life we pass such judgments as those given in the present experiment, and in much the same way, with about the same number of categories. We pronounce ourselves to have slept well or poorly or about as usual. Finer distinctions would probably have little or at most exceedingly variable meaning. With respect to the criteria on which such judgments are based there are also considerable individual differences. The number of hours slept through, the number and character of the dreams, the interval after retiring before sleep ensued, the number of times awakened during the night, general feelings of relief or languor after arising, etc., all play their part no doubt. And the judgment is at best only a secondary one, that is to say the quality of sleep is inferred from introspections and observations made during waking moments. In spite of this, few judgments of this subjective character would seem to have higher reliability than the individual's own opinion of the satisfactoriness of his slumber, and when the categories are limited to the three employed here, the judgments are delivered with a high degree of confidence. The reliability of the judgments is moreover emphasized by the consistent conclusions suggested by the various tables.

The statements of number of hours sleep are at best only approximate, in cases of impaired sleep. When the slumber was not disturbed the figures are more reliable, since all the subjects observed regular hours of retiring and arising. It will not be possible here to compare the individual subjects or the squad averages with each other, except in so far as the number of hours' sleep on control days is adopted as the normal in each case. A fairly constant average of about 7.5 hours sleep appears to be the normal for all of the subjects, as is indicated by the records for the week before the caffein doses began, and also by the records for the control days during the caffein experiments.

The records on sleep fall into two general sections, the first covering the 28 days of the caffein alkaloid experiments, and the second covering the 7 days of the experiments with syrups and carbonated water, with and without caffein contents. In the following tables the first column gives the averages for the first week, during which only sugar doses were given to all subjects. The second column gives the averages for the control days during the following three weeks. These two columns may then both be considered as normals. The third column gives the averages for the days on which the dose was either 1 or 2 gr. of caffein, the fourth column the records for the 3–4 grain doses, and the fifth column for the 6 gr. doses. The last column gives the final average for all the caffein days (1–6 gr. doses).

The individual subjects are grouped in squads according to the time at which the dose was taken and according to the distribution of the doses during the month.

Squad I., consisting of subjects 1, 4, 7, and 15, were the control squad, and ran throughout the four weeks on sugar doses only. Nevertheless their records have been averaged as though they had taken the caffein on alternating days, as was the case with squads III. and IV. The parentheses around their averages indicate then that these were not really caffein days, but days on which the caffein squads took the doses indicated at the top of the various columns. The sleep records of the individuals taking caffein may thus be compared with the control records of individuals taking only sugar on the corresponding days. The caffein records are thus trebly checked up—first by a normal week for all subjects, second by control days for all subjects during the following three weeks, and thirdly by a control squad running throughout the month on sugar doses only.

Squad II., consisting of subjects 8, 12 and 13 took caffein on three days and sugar on the following three days, at 10:30, followed in turn by three days of caffein, and so on throughout the experiment, except that there was only one day available for the 6 grain dose. The 1–2 grain records for this squad are the averages of 3 days of 1 grain and 3 days of 2 grain doses. The records for 3–4 grains are the averages of three 4 grain days, while the records for 6 grains are not averages but single records.

Squad III. took caffein and sugar doses on alternate days throughout the experiment, at the 1 o'clock lunch hour, thus giving two days for each of the 1, 2, 3, 4 and 6 grain doses. Squad IV. also alternated caffein with sugar doses throughout the month, with the same distribution of days as in the case of Squad III., the only difference being that the dose was taken in the middle of the afternoon instead of at the lunch hour. Squad III. consisted of subjects 3, 9 and 14, while Squad IV. contained subjects 5, 6, 10, 11 and 16.

Section 1. Experiments with Caffein Alkaloid

Table XCVI. gives the individual averages for quality of sleep during the first four weeks, and also the squad averages, with final averages for the caffein days and a grand average for each column for the three caffein squads.

Table XCVII. brings together the averages for each squad, at the same time giving the mean variation of each average and the

number of cases from which the average is in each case derived. The table also gives the final averages for the three caffein squads, the mean variation of the three squad averages from this final average, and the total number of cases for each kind of dose. The number of cases depends chiefly on the number of individuals making up the squad, and in the case of Squad II. on the fact that 3 grain doses were not administered and that only one 6 grain dose was given.

TABLE XCVI

INFLUENCE OF CAFFEIN ALKALOID ON THE QUALITY OF SLEEP

Squad	Subjects	First Week	Control Days	Caffein Doses 1–2 Gr.	3–4 Gr.	6 Gr.	Caffein Average
I.	1	180	190	(225)	(200)	(150)	(200)
Sugar only	4	200	230	(200)	(200)	(300)	(220)
	7	170	150	(175)	(125)	(100)	(140)
	15	200	230	(225)	(200)	(250)	(220)
	Av.	187	200	(206)	(181)	(200)	(195)
II.	8	220	220	250	266	300	273
Morning	12	200	210	200	200	300	233
Caffein 3 days	13	220	190	200	200	200	200
Sugar 3 days	Av.	213	207	216	220	266	234
III.	3	200	240	275	200	200	225
With lunch	9	220	190	225	200	250	225
Alternately	14	200	230	200	175	200	191
	Av.	213	220	233	192	217	214
IV.	5	230	200	250	250	300	266
Mid P.M.	6	200	190	175	175	250	200
Alternately	10	220	210	175	225	300	233
	11	200	210	250	250	200	233
	16	150	140	150	150	300	200
	Av.	200	190	200	210	270	226
Grand averages of Squads II., III. and IV.		208	206	216	207	251	224

The data presented in the two preceding tables seem to justify the following conclusions concerning the influence of caffein alkaloid, taken in its pure form, on the quality of sleep.

1. Doses smaller than 6 grains do not cause sleep impairment, so far as the squad averages indicate. The average M.V. of these squad averages is 38. Although the figures for Squad II. are larger for all doses of caffein the range is quite within the probable error except for the 6 grain doses where sleeplessness is clearly present

(Table XCVII.). Squad III. shows no sleep impairment whatever, the quality being reported even quite uniformly better on caffein days. Squad IV. similarly shows no deterioration in sleep quality until the 6 grain dose is reached, but the falling off at this point (270) is apparent. The final averages of the caffein squads show the rule clearly. Up to the 4 grain doses the sleep quality remains quite constantly about 209, but at 6 grains there is an abrupt falling off to 251 (Table XCVII.). Since these figures are the averages of 11 individuals, with daily records covering a period of 28 days, they have high reliability.

TABLE XCVII

THE SQUAD AVERAGES FOR CAFFEIN ALKALOID

Squad		First Week	Control Days	1-2 Gr.	3-4 Gr.	6 Gr.
I.	Av.	187	200	(206)	(181)	—
Sugar only	M.V.	47	35	35	30	—
	Cases	24	28	16	16	—
II.—10:30 A.M.	Av.	213	207	216	220	266
Caffein 3 days	M.V.	40	31	27	33	44
Sugar 3 days	Cases	18	30	18	9	3
III.	Av.	213	220	233	192	217
With lunch on	M.V.	31	40	50	15	72
alternate days	Cases	18	30	12	12	6
IV.	Av.	200	190	200	210	270
Mid P.M.	M.V.	33	49	50	36	39
Alternate days	Cases	30	50	20	20	9
Final averages of	Av.	208	206	216	207	251
caffein squads	M.V.	6	10	11	10	23
	Total cases	66	110	50	41	18

2. The influence of the caffein dose depends to a quite appreciable degree on the conditions under which the dose is taken, and especially on the time of day, the contents of the stomach at the time, and the frequency with which the dose is taken. This dependence is indicated by a comparison of the averages for Squads II., III. and IV.

(*a*) The greatest impairment of sleep quality is found in the case of those taking the doses on successive days (Av. 234), and this is true in spite of the fact that the dose was in these cases taken early in the morning, some four hours before Squad IV. and two to two and a half hours before Squad III. Had the dose been taken later in the day the difference would doubtless have been still greater. It is impossible to say, on the basis of the data at hand,

how soon this cumulative effect would be compensated by such processes of adaptation as are well recognized features of drug action.

(*b*) Next to this squad, the greatest sleep impairment is found with the group (Squad IV.) taking the caffein dose late in the afternoon, between meals and on an empty stomach (Av. 226).

(*c*) Quite in line with this fact is the further evidence that when the dose is taken along with food substance, as in the case of Squad III., who took the caffein at the lunch hour, there is absolutely no evidence of sleeplessness. The presence of food substance in the stomach seems not only to retard the action of the drug but to weaken or even completely neutralize its effect, so that the average for Squad III. (214) is actually better than their own average on control days (220), although this difference, since it is quite within the probable error, is not evidence of genuine superior quality. The lowest value for this squad is at the 1–2 grain doses (233) but this large figure is due solely to the one individual (subject 3, Table XCVI.) who reported poor sleep for several nights in succession, on control days (240) as well as on caffein days.

3. These results are confirmed by a more detailed study of the records of the individuals making up the various squads. Three subjects, 3, 13 and 14 are not affected even by the maximal 6 grain dose. Five remain unaffected until the 6 grain dose is reached, these being subjects 6, 9, 10, 12 and 16. Only three individuals of the total eleven show signs of disturbance before the 6 grain dose is reached, these being 5 and 8 (who report sleeplessness as soon as the caffein doses begin and show increasing impairment with larger doses) and 11 who reports 250 for 1–2 and for 3–4 grains but did not seem to be disturbed by the 6 grains.

4. The age of the individual does not seem to influence his susceptibility to the sleep disturbing effects of caffein. The three individuals who report poor sleep after the minimal doses are 24, 27 and 33 years of age, respectively, averaging 28 years. The five who were disturbed only by the 6 grains range from 21 to 33 years, averaging 26. The three who are not affected at all are 22, 27 and 39 years old, averaging 29.3 years. The figures thus show no correlation between age and the ease or degree of sleep disturbance. (See Table XCVIII.).

5. Previous caffein habits do not seem to modify the individual's susceptibility during the experiment. Table XCVIII. indicates for each subject the coffee or tea drinking habits indulged in before the experiments began, and reveals no uniformity. Individuals who were accustomed to the regular use of caffein-containing

beverages are to be found in each group along with those who have never used coffee nor tea, or have used them only occasionally.

6. So far as the present experiment is concerned, no sex differences in susceptibility are disclosed. Four of the subjects in the caffein squads were women. Of these two were affected by minimal doses, one by maximal doses only, and one not at all. Of the men, two were not affected at all, four were affected by the maximal dose only, and one by the minimal.

TABLE XCVIII

INDIVIDUAL DIFFERENCES IN SUSCEPTIBILITY

	Type	Subject	Age	Weight	Caffein Habit
1	Reacted to minimal doses	8	24	144	Used regularly
		5	33	105	Used regularly
		11	27	110	Abstainer
		Average	28	120	
2	Reacted to maximal doses only	12	24	160	Used regularly
		9	21	130	Abstainer
		6	33	125	Used regularly
		10	28	157	Occasionally
		16	24	174	Used regularly
		Average	26	149	
3	No reaction	13	22	175	Used regularly
		3	39	159	Abstainer
		14	27	193	Occasionally
		Average	29.3	176	

7. The only factor which correlates closely with susceptibility is weight. Table XCVIII. shows this correlation clearly. The average weight of those who are affected by the minimal doses is only 120 pounds. The average weight of those who are affected, but only by the maximal dose is 149 pounds, while the average weight of the three individuals who are not affected at all is 176 pounds. That is to say, the greater the body weight of the individual the greater the immunity to the sleep-disturbing influence of caffein. The two lightest subjects, 5 and 11, are in the susceptible group, while the heaviest woman and the two heaviest men are in the immune group. The relation between body weight and the action of drugs in a medicinal way is a well-recognized principle of pharmacology, and it is interesting to find such close confirmation of the principle in these introspective sleep records. It means simply that, when a fixed dose is administered, the heavy or large individual receives relatively a smaller dose, per unit of tissue, and the influence of the drug is

correspondingly reduced. Age and sex differences in the susceptibility to drugs are probably in many cases not true age or sex differences but differences based on variations in weight or size. A given amount of caffein, for instance, should be expected to produce greater sleep disturbances in a child than in an adult, not so much because of the child's immaturity as because of the fact that he receives a larger dose per unit of tissue.

Table XCVIII. presents the classification of the eleven subjects according to their susceptibility, giving at the same time their age, weight and caffein habit.

TABLE XCIX

EFFECT OF CAFFEIN ON AMOUNT OF SLEEP

		1st Wk.	Control	1-2 Gr.	3-4 Gr.	6 Gr.	Caf. Av.
Squad I.	Sugar only	7.45	7.40	(7.50)	(7.75)	(7.67)	(7.55)
II.	Three-day periods	7.13	7.63	7.46	7.57	7.07	7.37
III.	With lunch	7.43	7.47	7.57	7.33	6.40	6.90
IV.	Middle P.M.	7.20	7.46	7.38	7.00	6.30	6.88
Average of Caffein Squads II., III. and IV.		7.25	7.52	7.47	7.30	6.59	7.05

Table XCIX. gives the squad averages of the approximate number of hours' sleep, as well as the final average for the three caffein squads. The figures indicate hours and decimal parts of an hour. The indications here thoroughly bear out the conclusions based on the judgments of sleep quality. The control squad (I.) shows little variation as the experiment proceeds, the average amount of sleep being uniformly about 7.5 hours. Squad II., taking caffein in the morning, proceeds in much the same way until the 6 grain dose is given, when the time drops to about 7 hours, a loss of half an hour sleep. The amount of sleep for Squad III., taking dose with lunch does not diminish appreciably until the 6 grain dose is given, when the earlier average of 7.4 hours abruptly drops to 6.4 hours, a loss of one hour. The figures for Squad IV., taking dose in the afternoon, between meals, drops off .5 hour at the 3–4 grain doses, and still another .5 hour at the 6 grain dose. Comparing the caffein average with the control average, Squads III. and IV. lose on the whole for 1–6 grain doses, .6 of an hour, while Squad II. averages, for the whole range of doses, a loss of only .3 of an hour. The grand average of the caffein squads shows a slight tendency to fall off for the smaller doses, with an abrupt loss of .7 of an hour at the 6 grain dose, while the grand average for the total range of doses (1–6 grains) shows a loss of half an hour, the figure falling from 7.5 hours on control days to 7.0 hours. The individual records show nothing new, and are consequently not given.

Section 2. Influence of Syrups, with and without Caffein, on the Quality of Sleep

This experiment covered one week. On two days no dose at all was given. On two days soda fountain syrup, containing no caffein, was served with carbonated water. On the remaining three days, which were, however, scattered throughout the week, varying amounts of the syrup were given, served with the carbonated water as before, but containing caffein alkaloid (1.2 grains per glass). On one day 1 glass was taken, on another 3 glasses and on the third day 5 glasses. In all cases the drink was taken in the middle of the afternoon. When the large amounts were taken the drinks were distributed over a period of 2 or 2.5 hours. When the small amounts were taken the 3:00 o'clock hour was chosen for the drink. In this experiment 12 subjects were used, all of whom had taken part in the previous experiment. No squad division was made, the days on which no dose was taken (called "blank days" in the table), served as control days for the whole group.

TABLE C

Influence of Syrups, with and without Caffein

Character of the Dose	Sleep Quality Average	Sleep Quality M.V.	Hours Sleep Average
Blank days	179	54	7.48
Plain syrup, with carbonated water	208	23	7.69
Syrup, with caffein,			
1 glass (1.2 gr.)	180	30	7.42
3 glasses (3.6 gr.)	209	49	7.16
5 glasses (6.0 gr.)	250	60	6.75
Syrup, with caffein, average	213	46	7.11

Representing as before, the *normal* quality of sleep by the value 200, letting 100 represent sleep introspectively judged as *better than usual,* and 300 sleep judged as *worse than usual,* the following table (C.) results from the week's experiment on the 12 subjects. The figure for "blank days" is thus an average of 12 records on each of 2 days an average of 24 cases. The figure for "syrup days" is an average, in the same way, of 24 cases, while each of the "caffein" figures is an average of 12 records.

The results of this experiment completely confirm the conclusions presented in the first section. The "blank days" have a good average quality (179), but no better than that for the day of the 1 glass of syrup drink, containing 1.2 grains of caffein. The 3.6 grain dose of caffein results in a poorer quality of sleep than that on

the "blank days," but no poorer than that reported on the days on which the same amount of plain syrup was taken (3.6 gr. caffein—209, plain syrup—208). Moreover both these figures are approximately ordinary sleep (200). But on the days on which the drink contained 6 grains of caffein there is clear evidence of sleep impairment (250). This is just the point at which the doses of pure caffein alkaloid produced marked signs of sleep disturbance. The average for the three caffein days (1–6 gr.) is poorer than that for the plain syrup days (caffein 213, syrup 208), while the average for "blank days," is better than either of these two (179).

The reports of approximate amount of sleep point in the same direction. The "blank days," the plain syrup days and the 1.2 gr. caffein day all yield the well established normal of about 7.5 hours of sleep. The average after the 3.6 gr. caffein dose appears to be only slightly less, being 7.16, a loss of about .25 hour. But after the 6 grain dose there is an abrupt falling off, the average being only 6.75 hours, a loss of .75 hour as compared with the normal amount. Not only in their relative amounts, but in absolute magnitude as well, the figures for sleep quality and for amount of sleep, in this second section, correspond closely to the figures yielded by the experiments reported in the preceding section on the effects of pure caffein doses.

It should be remarked that in no case did the subjects know the nature of the dose which they were taking at the time. The only indications they had throughout the experiment were based on the after effects of the drug. In Section 1, each subject received a capsule daily, this capsule sometimes containing caffein in amount known only to the director of the experiment, and at other times only sugar of milk. The control capsules were varied in size, as were the caffein capsules of necessity. In Section 2, the subjects knew only that they were taking soda-fountain drinks. There was said to be a slight variation in the taste from time to time, but this was supposed, by the subjects, to be due to the degree to which the syrup had been mixed with the carbonated water, to its temperature, etc. The disturbing factors of suggestion, interest, excitement and unequal introspective attention were thus effectually avoided.

Summary

By way of summary we may say: Small doses of caffein alkaloid (1–4 grains), taken either in the pure form or accompanied by small amounts of syrup, do not produce appreciable sleep disturbance except in a few individual cases. Doses larger than these

(6 grains, in the present experiment) induce marked sleep impairment with most subjects, though even here a few individuals show complete resistance to its effects. The effects are greatest when the dose is taken on an empty stomach or without food substance, and when it is taken on successive days. The effect of the drug does not seem to depend on the age, sex, or previous caffein habits of the individual, but varies inversely with increase in body weight. These conclusions hold both for the quality and for the amount of sleep.

CHAPTER XIV

The Influence of Caffein on General Health

The individual health record which each subject kept throughout the experiment has already been described in the section on "Supplementary Information" in Chapter II. Since the investigation was concerned chiefly with proficiency in the mental and motor tests, the chief value of the daily health book lay in its service as a check on the records made by the subject and as a guide to the director in the administration of the doses. It was for these two purposes that the health introspections were originally recorded. No definite attempt was made to study the physiological action of caffein on the human system, although the conditions of the experiment afforded excellent opportunity for such observations to be made on at least several of the special organs. The introspections recorded in the health book were more or less general in character whereas only special and detailed examination would have served to determine any local physiological effects that might have resulted from the caffein administration.

Nevertheless examination of the daily reports suggests that they have in themselves a certain positive value, aside from their bearing on the test records. It is not often that careful introspections of 16 individuals over a period of 40 days of carefully controlled drug administration can be presented. Moreover, since the general feeling of well-being will be reflected in the individual's efficiency in the performance of mental and motor tests, we have in these daily records an indirect measure of just those factors which it was the chief purpose of the investigation to examine. Comparison of these reports with the actual changes in efficiency as measured by the tests shows a close correlation between the two sets of results. For these reasons it seems worth while to publish the daily introspections in full. The following pages of this chapter contain the daily records of all the 16 subjects from February 10 to March 2, the period of three weeks during which the caffein doses were administered in Experiment *A*. The records have been copied directly from the individual books, the only changes consisting of occasional abbreviations and grammatical corrections. The records of each of the subjects who received caffein are followed by a brief statement

of general results in the case of the subject in question. At the close of the chapter is given a general statement of the results for each squad. These results are stated only tentatively, completer interpretation being left for such readers as have fuller medical knowledge than the writer.

At the close of the experiments each subject was asked whether or not he had read, during the investigation, any general or special treatise concerning the supposed effects of caffein, and whether or not he felt that his introspections had been in any way influenced by suggestions received in this way, or by his general knowledge or expectation. No subject had ever read any account of the action of caffein other than the incidental references to it found in the text-books of physiology used in the elementary schools.

The following four subjects comprised the control squad and ran through the whole period on sugar doses only, given at 1:00 P.M.

Subject 1, M., 39, , Regular User

Feb. 10. Felt and slept as well as usual since the experiments began.

11. Felt duller than usual to-day. Slept normally, 6.25 hrs.

12. Felt normal to-day aside from a slight headache in the morning. Much better than yesterday. Slept about 6 hrs., but woke up tired a full hour before necessary. Sleep fully normal while it lasted.

13. Felt duller than yesterday but not so dull as Saturday. Slightly constipated. Slept soundly about 6 hrs., being awakened by noise next door. Slept better than usual since the experiments began.

14. Felt normal to-day. Slept soundly for about 6 hrs.

15. Felt fine this morning but dull this afternoon. Slight inclination to headache in afternoon but this gave way to a heavy feeling in the head. Slept not so well as usual, about 5.75 hrs.

16. Felt depressed during the morning but better in the afternoon. Headache and dull feeling gone in afternoon. Slept as soundly as usual for 6 hrs.

17. Normal during morning and early part of the afternoon, but about the middle of the afternoon I seemed to have a slight fever and from that time on did not feel so bright as usual. Slept normally for 6 hrs.

18. Felt normal to-day except in the matter of nervousness which may have been due to the completion of some work not connected with the experiments. Have certainly been more nervous than before the experiments began. Slept as well as usual, 6 hrs.

19. I seemed to be normal up to 11:00 A.M., when a dizzy spell lasting about 20 minutes began, which was succeeded by a dull but not severe headache. In the P.M. between 2:00 and 4:00 the headache seemed slightly more troublesome. Was awakened in the middle of the night by no apparent cause but went to sleep again probably in half an hour. 6 hrs.

20. Felt normal this morning but got drowsy about 3:00 P.M. and have felt duller than usual since. Slept as well as usual about 6 hrs.

21. Felt normal to-day, but slightly nervous. Slept as well as usual.
22. Normal during morning. In afternoon a slight headache came on together with a slight fever. Felt dull since about 2:30. Slept worse than usual, waking early. About 5 hrs.
23. Felt normal to-day with exception of slight tendency to nervousness and weakness. This condition has been uniform throughout the day. Slept as soundly as usual, about 5.75 hrs.
24. Aside from a tired feeling around the eyes I have felt as well as usual to-day. Between 11:00 and 12:00 I seemed to become slightly flushed but was probably not feverish. Felt better in the afternoon. Slept soundly as usual for 6 hrs.
25. Felt slightly better than usual to-day. Slept about 6 hrs., but did not wake so refreshed as yesterday.
26. A little tired early in the morning but soon recovered my usual form. Slight tendency toward headache toward noon and after that felt duller than usual for about three hours. Slept as usual, for approximately 6.25 hrs.
27. Felt dull this morning and had shooting pains in the back of my head especially after 11:00 A.M. Felt much brighter in the afternoon, and as well as usual. Slept better than usual, for 6.25 hrs.
28. Felt better than usual all day. Not one unfavorable symptom. Slept as well as usual for about 6 hrs.

Subject 4, M., 19, 124, Moderate User

Feb. 10. Felt as well as usual during the day. During the evening I felt more wide awake than usual. Sleep ordinary, 8.5 hrs.
11. As usual during day. Sleep as well as usual, 7.5 hrs.
12. As usual during day. Sleep as well as usual, 8 hrs.
13. As usual during day. Sleep as well as usual, 8 hrs.
14. Felt as well as usual. Did not sleep well toward morning but woke up several times. 8 hrs.
15. As usual during day. Sleep as usual. 8 hrs.
16. As usual during day. Sleep as usual. 8 hrs.
17. As usual during day. Sleep as usual. 7.5 hrs.
18. As usual during day. Sleep as usual. 7.5 hrs.
19. As usual during day. Sleep as usual. 8 hrs.
20. Felt as usual. Sleep poorer than usual. 8 hrs.
21. Felt as usual. Sleep as good as usual. 8 hrs.
22. Felt as usual. Sleep as good as usual. 8 hrs.
23. Felt as usual. Sleep as good as usual. 8 hrs.
24. Did not feel as well in the P.M., being quite tired. Did not sleep quite as well as usual. 7.5 hrs.
25. Slight headache all day. Slept as well as usual. 7.5 hrs.
26. Slight headache all day. Slept as well as usual. 7.5 hrs.
27. Felt as well as usual during day. Did not sleep quite as well as usual. 8.5 hrs.
28. Felt as usual during the morning. Slept as well as usual, 8.5 hrs.

Subject 7, M., 19, 153, Moderate User

Feb. 10. Feeling as usual. Slept a little better than usual, 7.5 hrs.
11. Quite drowsy in forenoon and early afternoon. Later felt as usual. Slept brokenly, but longer than usual, 9.5 hrs.
12. A little drowsy about noon. Later as usual. Slept as usual, 7.5 hrs.
13. More tired than usual to-day. Slept unbrokenly for 6.5 hrs.
14. More tired than usual. Slight headache. Slept 7 hrs., more soundly than usual.
15. Am feeling a little tired, more than usual. Was quite sleepy in the afternoon. Slept about 8 hrs., which is a little more than usual. Slept evenly and a little better than usual.
16. Felt better than usual during the day. Slept better than usual, for 9 hrs., unbrokenly.
17. Felt better than usual during day. Have slight headache now. Slept about as usual for about 9 hrs.
18. As usual during the day, except for slight headache at the beginning of the forenoon, which steadily diminished. Slept about as usual, for 7.5 hrs.
19. Felt very sleepy during the day. Have a slight headache now (6:30). Slept 9 hours, about as usual.
20. A little drowsy in afternoon and headache in evening. Slept about as usual for 7 hrs.
21. Felt better than usual during day, but have slight headache this evening. Slept a little better than usual for 9 hrs.
22. Felt a little drowsy in afternoon, otherwise a little better than usual. Slept about as usual for 10 hrs.
23. Felt about as usual during day except for slight headache toward evening. Slept 8 hrs. about as well as usual.
24. Better than usual during day with slight headache toward evening. Slept better than usual for 7.5 hrs.
25. As usual during morning with headache in afternoon. Slept about as usual for 8 hrs.
26. Felt very badly all during the day, which is not as usual. Have an intense headache now. Slept as usual for about 9 hrs.
27. Felt as usual to-day. Slept a little better than usual for about 8 hrs.
28. Felt a little better than usual to-day. A little blue toward evening, with a slight headache. Slept about as usual for about 7 hrs.

Subject 15, F., 34, 108, Occasional User

Feb. 10. Felt and slept about as usual. 8.25 hrs.
11. Felt better and more rested than I have since the tests began. Slept 8 hrs. as well as usual.
12. Felt and slept about as well as usual. 8 hrs.
13. As well as usual except at 10:00 A.M., when I was nervous on account of the baby crying so for me. Slept as usual, 8 hrs.
14. Perhaps a little more tired than yesterday. Didn't sleep so well as usual. 7 hrs.
15. Slept and felt as well as usual.
16. Began as usual but got tired and nervous in the afternoon. Slept as usual, but now have unpleasant dreams oftener. 8.5 hrs.

17. As well as usual and much less tired than yesterday. Did not sleep as well as usual on account of the wind. 8 hrs.
18. Felt as usual. Not tired at all as I am some evenings after the day's work. Slept as usual. 7.5 hrs.
19. Felt and slept as usual to-day. 8 hrs.
20. Felt as well as usual until 5:30, then I had a slight headache. Did not sleep quite so well as usual. 7.5 hrs.
21. (—)* As well as usual. My eyes have been troubling me a great deal for the past week. Slept as well as usual. 8 hrs.
22. As well as usual excepting a slight headache in afternoon. Sleep as good as usual. 8 hrs.
23. Felt dull all day, and had headache at evening test. Slept as well as usual after I got to sleep, but was kept awake later with the baby. Also had headache. 7 hrs.
24. (—) Felt as well as usual. Did not sleep as well as usual and had bad dreams. 7.5 hrs.
25. As well as usual, but tired at the last test. Sleep as usual. 9 hrs.
26. Felt as usual all day. Slept as well as usual. 8.5 hrs.

Subject 3, F., 39, 159, Abstainer, Squad III

Feb. 10, 1 gr. sugar, 1:00 P.M. with lunch. (Morning) Feel as usual to-day. (Evening) Feel as usual, not much tired. Went to bed at 10:30, had slight sore throat and slept poorly. Woke at 6:45.

Feb. 11, 1 gr. caffein, as above. (Morning) Feel all right. (Evening) Felt as usual all day. Slept better than last night, went to bed at 11:00 and woke at 6:30.

Feb. 12, 1 gr. sugar, as above. (Morning) Feel as usual this morning. (Evening) More tired than usual. No other difference. Went to sleep at 9:15, woke at 6:30. Slept poorly the latter part of the night. Sleep not so good as usual.

Feb. 13, 1 gr. caffein, as above. A little tired this morning. (Evening) Less tired than this morning. Felt as usual to-day. Went to bed at 10:30, woke at 6:45. Slept better than night before but not so well as usual.

Feb. 14, 2 gr. sugar. (Morning) feel as usual. (Evening) Less tired than yesterday and day before. Otherwise as usual. Bed at 10:30, woke at 6:30, did not sleep as well as usual the latter part of the night.

Feb. 15, 2 gr. caffein. (Morning) Feel as usual. (Evening) Felt as usual all day, bed at 10:30, woke at 6:30, did not sleep as well as usual.

Feb. 16, 2 gr. sugar. (Morning) As usual this morning. (Evening) Felt as usual all day. Slept almost as well as usual (8 hrs.), woke with a slight headache.

Feb. 17, 2 gr. caffein. (Morning) (—) As usual this morning. (Evening) No headache since noon. Slept as well as usual, 7.5 hrs.

Feb. 18, 3 gr. sugar. (Morning) As usual. (Evening) Unusually tired this afternoon and sleepy. Feel better in evening, after short rest. Slept from 11:00 to 6:30, as well as usual.

Feb. 19, 3 gr. caffein. (Morning) As usual. (Evening) Less tired than usual. Slept from 10:00 to 6:30, as well as usual.

Feb. 20, 3 gr. sugar. (Morning) Feel all right. (Evening) Tired and nervous after lunch, feel all right this evening, and as usual. Slept as well as usual, from 11:20 to 6:30.

* These marks (—) indicate beginning and end of menstrual period.

Feb. 21, 3 gr. caffein. Felt a trembling sensation all day, more noticeable this afternoon. Otherwise as usual. Slept 7.5 hrs. as well as usual.

Feb. 22, 4 gr. sugar. (Morning) As usual. (Evening) As usual all day. (—) Slept 8 hrs. very well, as usual.

Feb. 23, 4 gr. caffein. (Morning) As usual. (Evening) More nervous than usual after lunch. Otherwise as usual. Slept 8 hrs., well as usual.

Feb. 24, 4 gr. sugar. (Morning) Normal. (Evening) Have felt as usual to-day, have not been nervous, as was the case yesterday. Slept 8 hrs. as well as usual.

Feb. 25, 4 gr. caffein. (Morning) Feel all right this morning. (Evening) As usual to-day, slept from 11:30 to 6:45.

Feb. 26, 6 gr. sugar. (Morning) Feel as usual. (Evening) Drowsy in the afternoon, slept as usual, but over 9 hrs.

Feb. 27, 6 gr. caffein. (Morning) As usual. (Evening) Slightly dizzy at 1:45. Been nervous during the afternoon. Baby kept me awake until 12. Couldn't go to sleep before 1:00. Slept poorly until 6:30.

Feb. 28, 6gr. sugar. (Morning) Feel all right. (Evening) As usual all day. Slept almost as well as usual, 6.5 hrs.

March 1, 6 gr. caffein. (Morning) Feel as usual, all forenoon. (Evening) Have been nervous and unsteady this afternoon, slept from about 11:00 to 6:40, and about as well as usual.

March 2, 6 gr. sugar. Felt as usual to-day, except that I seemed to have less energy after about 12:00 o'clock.

General Result.—Nervous feeling from doses of 3, 4, and 6 gr. of caffein. Suggestion of dizziness and sleeplessness following the first 6 gr. dose.

Subject 9, M., 21, 130, Abstainer, Squad III

Feb. 10, 1 gr. sugar, 1:00 P.M., with lunch. (Morning) As well as usual. (Evening) As usual through day. Lost three hours sleep due to screaming of woman in same apartment house.

Feb. 11, 1 gr. caffein, as above. As usual throughout the day. Slept as usual, 7 hrs.

Feb. 12, 1 gr. sugar. As usual all day. Same for sleep.

Feb. 13, 1 gr. caffein. As usual all day. Same for sleep.

Feb. 14, 2 gr. sugar. As usual all day. Same for sleep.

Feb. 15, 2 gr. caffein. As usual all day. Same for sleep.

Feb. 16, 2 gr. sugar. As well as usual, drowsy all day, especially in the forenoon. Slept as usual.

Feb. 17, 2 gr. caffein. Felt as usual. Sleep poorer than usual, slept only 6.5 hrs.

Feb. 18, 3 gr. sugar. Sleep and condition same us usual.

Feb. 19, 3 gr. caffein. Everything as usual.

Feb. 20, 3 gr. sugar. Felt as usual. Slept better than usual, 7.5 hrs.

Feb. 21, 3 gr. caffein. (Morning) As well as usual. (Evening) A little nervous in the afternoon. Slept 7.5 hrs. and as well as usual.

Feb. 22, 4 gr. sugar. Everything as usual.

Feb. 23, 4 gr. caffein. (Morning) Well as usual. (Evening) Pain in stomach in afternoon, also very nervous. Slept as usual.

Feb. 24, 4 gr. sugar. Everything as usual.

Feb. 25, 4 gr. caffein. Everything as usual.

Feb. 26, 6 gr. sugar. Everything as usual.
Feb. 27, 6 gr. caffein. (Morning) as usual. (Evening) Nervous in the afternoon. Slept as usual.
Feb. 28, 6 gr. sugar. Everything as usual. Slept two hours in the afternoon. Evening sleep as usual.
March 1, 6 gr. caffein. (Morning) As usual. (Evening) Nervous in the afternoon. Did not sleep well (lost three hours' sleep on account of a robber in the house).
March 2, sugar. As well as usual. Sleepy in afternoon.

General Result.—Nervousness for doses of 4 and 6 gr. No indications of sleep disturbance as result of caffein. Stomach pains mentioned once, after 4 gr. caffein dose.

Subject 14, M., 27, 193, Occasional User

Feb. 10, 1 gr. sugar, 1:00 P.M., with lunch. Felt almost ordinary to-day (this subject had been having a bad cold). Cold is disappearing and nose bleed has not bothered me any. Slept as usual, 8 hrs.
Feb. 11, 1 gr. caffein, as above. No difficulty this morning. (Evening) Have felt better to-day than for a week. Slept better than usual for 8 good hours.
Feb. 12, 1 gr. sugar. Slight headache about 9:30 A.M. (Evening) Feel better than usual, and have all day. Slept as usual for 8 hrs.
Feb. 13, 1 gr. caffein. (Morning) Feeling better than usual, or at least better than first week of experiment. (Evening) As usual all day. Slept as usual for 8 hrs.
Feb. 14, 2 gr. sugar. (Morning) Left ear slightly inflamed and sore. (Evening) With exception of my ear, which is feeling better this evening, I have felt normal all day. Have a slight heartburn late this evening, but not sufficient to make me feel worse than usual. Slept better than normal for 9 hrs.
Feb. 15, 2 gr. caffein. (Morning) Ear about as yesterday. Dropping sweet oil in it. (P.M.) Feel just a little tired this evening, especially in the arms, due, I think, to the tapping test, which seems to tire me. Would say not quite normal. Slept as usual, for 7 hrs.
Feb. 16, 2 gr. sugar. (Morning) Tonsil still swollen slightly and left ear still sore (prescriptions given by medical assistant for ear, throat and general system). Felt somewhat dull all morning. (Evening) Found that I was able to do some fair studying from 1:30 to 3:00 P.M. and during the laboratory periods. I do not feel as full of energy as is normal for me. Slept worse than usual, for 8 hrs. Woke up several times.
Feb. 17, 2 gr. caffein. Felt bad all day, but not particularly dull. Ear does not bother me any more. Have a sort of heartburn. Since I have not been taking regular exercise I started in with a run at the gym before the 5:30 test and think the heating up entered into my evening records. Slept not quite normal for 8 hrs.
Feb. 18, 3 gr. sugar. Have not felt normal to-day, due to my extremely sore throat. Burning sensation away down in my throat all the time. Have a feeling of fatigue. Slept well for about 7.5 hrs., better than on two former nights, so almost normal.
Feb. 19, 3 gr. caffein. (Morning) Felt much better than yesterday. (Evening) Felt as usual to-day. Ear and throat better. Do not feel fatigued as last night. Slept normal for 7.5 hrs.

Feb. 20, 3 gr. sugar. Felt as usual for the day. Ear and throat still sore. Not particularly bright so far as intelligence goes. Seemed hard for me to follow cases in law class at 2:00 P.M. Slept as usual for 7 hrs.

Feb. 21, 3 gr. caffein. (Morning) My eyes are tired and rather strained. (Evening) Felt normal to-day, but eyes continue tired. Slept better than usual, and was also better able to study than usual in the late evening.

Feb. 22, 4 gr. sugar. Normal all day. Eyes not quite so tired. Slept better than usual, for about 7 hrs.

Feb. 23, 4 gr. caffein. (Morning) Felt better than usual all morning, and up until about 2:30 P.M., when I began to feel rather shaky, nervous. Through the test I felt queer and wanted to get outside and wear off my nervousness. No headache, but the muscles of my arm seem shaky. Don't seem to have the usual control over them. Feel a kind of burning sensation from my stomach and on up to my throat. Slept as usual for 7.5 hrs. Was awakened once along towards morning, but had no trouble in going back to sleep again.

Feb. 24, 4 gr. sugar. Felt quite normal all day. Have not felt nervous as yesterday afternoon. Slept for 8 hrs., about as usual.

Feb. 25, 4 gr. caffein. I felt, I should say, better than usual until this afternoon, about 3:00 P.M. However I did not feel so nervous as day before yesterday afternoon (Feb. 23), until during the last test (5:30–6:30 P.M.). My lower arms feel sort of wobbly as before. The average for the day would be about normal or a little below if anything. Slept as usual for 7 hrs.

Feb. 26, 6 gr. sugar. Felt normal all day. No nervousness in forearms as on some other afternoons. Slept as usual, 7 hrs.

Feb. 27, 6 gr. caffein. Felt normal all day until about 2:00 P.M. I was trying to read some cases in Constitutional Law and suddenly found that I was making little headway. Noticed a headache come on me which gradually got worse until about 3:30 P.M. Head ached in front above my eyes. My ears burned and are still burning. This is the first time I have had a headache during the experiment. I don't remember having had a headache for several months. After 4:00 P.M. I got out in the air with Ames and walking down to 125th St. we bowled a couple of games. During the first game I was suddenly conscious that my head was not aching. I now feel much better except that my forearms feel nervous and my ears are still burning. Have also, since 5:30 been feeling slightly sick at the stomach. Slept as usual for a little over 8 hrs.

Feb. 28, 6 gr. sugar. Nothing unusual or exciting to-day, except the fact that I felt awfully drowsy while studying here in the laboratory from 2 to 3 P.M. On the whole have felt quite normal. Slept fine for a good 9 hrs. I do not have any difficulty in going to sleep, nor has my sleep been restless. Have always heard that coffee kept one awake and caused them to awaken during the night. I have had no trouble in going to sleep, and my sleep has, almost without exception, been sound.

March 1, 6 gr. caffein. Felt normal up to about 3:30 P.M., when I began to feel somewhat nervous, but not nearly so bad as on former days, and particularly day before yesterday. Went to the gym 4 to 5 P.M., and while feeling very near normal now (5:30) I am weak and the muscles of my lower arms feel peculiar and unsteady. Slept a little less than 7 hrs., and not quite as well as usual.

March 2, sugar. I have felt normal all day. Have not felt any marked nervousness as on some previous days.

General Result.—No indications of impaired sleep. Nervousness after doses of 4 and 6 grains of caffein. Suggestions of heartburn and stomach pains after large doses. Headache after 6 gr.

Subject 5, F., 105, Regular User, Squad IV

Feb. 10, 1 gr. sugar, middle of afternoon. My head has felt dull all day, but was more clear just at noon than at any other time. (Evening) Feel more tired than usual. Slept 8 hrs., about as well as usual.

Feb. 11, 1 gr. caffein. About as usual to-day. Sleepy and tired in evening. Slept 7 hrs., and about as usual.

Feb. 12, 1 gr. sugar, as above. About as usual all day. (—) Slept quite well, usual time.

Feb. 13, 1 gr. caffein, as above. Felt about as usual. Very stupid just after lunch. Did not sleep as well as usual owing to commotion in the neighborhood. About 6.5 hrs.

Feb. 14, 2 gr. sugar. To-day I have had to force myself more than usual to try to keep up to my ordinary work. Am so hungry just now that my head aches, and I feel all gone. (Evening) Felt pretty well, but could not go to sleep till after midnight. Then slept as well as usual.

Feb. 15, 2 gr. caffein. (Morning) Felt about as usual. (Evening) A little light-headed and dizzy this afternoon. During the last few tests I was very faint and had a queer sick feeling at times. My mouth felt quite as if the saliva would start faster than I could swallow it and my limbs had a numb feeling after I reached home. Went to bed directly after dinner and rested as well as usual, sleeping about 9.5 hrs.

Feb. 16, 2 gr. sugar. (Morning) A bit weak and light-headed. During the early part of the day I felt very tired. These feelings gradually wore off and this evening I feel pretty well except a little more tired than usual. Slept about as usual, for 8 hrs.

Feb. 17, 2 gr. caffein. All day have felt very dull. During the middle of the day my head ached quite a little but toward evening it cleared up some, although it still aches. During the early evening this headache grew much worse, the tense feeling at the back of the head made it feel as if something would burst. By taking a very hot bath I managed to relieve it somewhat, but slept much worse than usual, for about 6 hrs.

Feb. 18, 3 gr. sugar. All day have had a very tense feeling at back of head. Just before lunch my head felt as if something in it would snap. After resting this feeling was relieved but is not all gone. My throat is somewhat sore to-night. Slept as usual, 7 hrs.

Feb. 19, 3 gr. caffein. Head has felt lame all day, not enough to call a headache except just after lunch, when it felt very drawn and tight. Much better after resting. Slept as usual till 5 A.M., when aroused by noises in the court. 6.75 hrs.

Feb. 20, 3 gr. sugar. Felt quite normal to-day, very little of the tight feeling in my head. Slept as usual, about 8 hrs.

Feb. 21, 3 gr. caffein. Felt better than usual to-day. Slept as well as usual, 8 hrs.

Feb. 22, 4 gr. sugar. Felt about as usual to-day, except just after lunch, when my head had quite a little of that drawn feeling at the back. Slept not quite as well as usual, for about 7 hrs.

Feb. 23, 4 gr. caffein. (Morning) About as usual. (Evening) This afternoon during the last two tests I have felt excited and very trembly. My arms feel very weak and it is hard to control the muscles. In walking back from home for the 3:00 o'clock test I felt light-headed, but otherwise perfectly well. Did not sleep quite as well as usual, could not go to sleep for some time after going to bed. About 6 hrs.

Feb. 24, 4 gr. sugar. A cold in my head has made it very hard to concentrate to-day. Congested feeling in the head, and since the latter part of the afternoon my head has ached a little, as well as every bone in my body. Am very tired this evening. Slept very soundly, and better than usual, about 8.5 hrs.

Feb. 25, 4 gr. caffein. (Morning) about as usual. (Evening) Just after lunch was very sleepy and dull. Very nervous during the last tests on account of a visitor to the laboratory. Slept much worse than usual, could not close my eyes for some time and had a drawn feeling at the back of my head again. Very nervous and did not go to sleep till after 1:00 o'clock, then slept for about 4.5 hrs.

Feb. 26, 6 gr. sugar. All day have been exceedingly tired, just after lunch felt almost exhausted and very sleepy. Drawn feeling at back of head. Slept about as usual, but awakened with a very bad headache.

Feb. 27, 6 gr. caffein. (Morning) Head ached very hard all morning, the pain being hardest just after lunch. (Evening) All the afternoon, while my head has been better, I have felt very weak and light-headed and even sort of faint. Arms and limbs have had a numb sort of feeling, and have been very cold. After resting at 1:30, on getting up found the veins in arms and hand very swollen. Felt very weak all during the evening, and for awhile my ears felt as if something in them would burst. Retired early but could not go to sleep for a long time, not till midnight. Slept very lightly about 5.5 hrs.

Feb. 28, 6 gr. sugar. Have been about as usual to-day, was unable to take my usual afternoon's sleep, being perfectly wide awake. At night was wakeful for a short time, then slept about as usual, 7 hrs.

March 1, 6 gr. caffein. (Morning) Some tired, but felt all right otherwise. After lunch, while at home, began to feel badly, my head felt very light and my arms and limbs numb. Brain unusually active, so much so that it gave me a wild kind of feeling and I did not like to stay alone. (Evening) After coming back to the laboratory the light-headed feeling grew worse. I scarcely knew what I was doing and my limbs were very cold. It was extremely hard for me to breathe, and the beating of my heart seemed to choke me. Was very restless at night, did not go to sleep till after midnight, and then awakened a number of times for just a few minutes. Dreamed all night. Slept worse than usual, for about 5.5 hrs.

March 2, sugar. Have had some sore throat all day, and have been tired, a little more so than usual.

General Result.—The symptoms reported by this subject were all present in her accounts of the first week during which sugar doses only were given. That she was very nervous and quite unfitted for the strenuous life required during the experiment is obvious. Several spells characterized by fainting and chill and numbness, occurring during the course of the experiment, required the aid

of the medical adviser. These attacks occurred on control days as well as on caffein days. The drawn feeling in the head, the tenseness and difficulty in sleeping were present before the caffein doses began. This condition was no doubt aggravated by the severe strain of undergoing the tests, but it is also obvious that all the symptoms were intensified by the larger caffein doses. The drawn feeling in the head was more pronounced and the numbness and coldness and lightheadedness are more frequently mentioned and seem to have been more annoying. Impairment of sleep on caffein days is also apparent for doses larger than 2 gr.

Subject 6, F., 33, 125, Regular User, Squad IV

Feb. 10, 1 gr. sugar, middle of afternoon. Felt unseated all morning, but as usual again at 6:30. Eyes tired. Slept well as usual. 7 hrs.

Feb. 11, 1 gr. caffein, as above. As usual. Did not feel at all tired until the last hour. Slept as usual, for 7 hrs.

Feb. 12, 1 gr. sugar. As usual. Slept well as usual from 11 to 2. Very brokenly from then to 6:30. Think it was due to nervousness from being alone.

Feb. 13, 1 gr. caffein. Felt and slept as well as usual. 7 hrs.

Feb. 14, 2 gr. sugar. Felt and slept as well as usual. 6 hrs.

Feb. 15, 2 gr. caffein. As usual except for aching and weakness in arm. Slept as well as usual, but for only 5 hrs.

Feb. 16, 2 gr. sugar. As usual except very sleepy, probably due to loss of sleep last night. Slept as usual for 6.5 hrs.

Feb. 17, 2 gr. caffein. Unusually sleepy about noon, probably due to the weather. Slept better than usual, for 6 hrs.

Feb. 18, 3 gr. sugar. Everything as usual. Arms feeling better. Slept as usual for 7 hrs.

Feb. 19, 3 gr. caffein. No change, except unusually shaky in my arms. Slept as usual, for about 6 hrs.

Feb. 20, 3 gr. sugar. Very sleepy about noon, but feeling as usual at 6:30. Arms steadier than yesterday. Slept as usual, about 6 hrs.

Feb. 21, 3 gr. caffein. Severe headache during the first hours of the day. Felt as though I had a tight band round my head. As usual at 6:30. Slept better than usual, for 7 hrs.

Feb. 22, 4 gr. sugar. As usual. Slept better than usual for 7.5 hrs.

Feb. 23, 4 gr. caffein. As usual until the last period. So weak and shaky during that hour that I could scarcely control any muscle in my body. Also a choking sensation in my throat. Head hot and hands and feet cold. Slept more soundly than usual, for 7.5 hrs.

Feb. 24, 4 gr. sugar. Felt very miserable all day without any decided pain. Aching in back and limbs, a little headache through my temples, a dimness in my vision at times, and my head hot and hands and feet cold were the chief characteristics. My nerves seemed to be on a strain all the time. Slept as usual, for about 8 hrs.

Feb. 25, 4 gr. caffein. Felt some better than yesterday. Slight headache during the middle of the day and weakness in arms and back all day. Very nervous during the last period. Think it was due to visitors watching the tests.

Slept very lightly and brokenly, for about 6 hrs. Extremely nervous all night, with pain in back of head. Retired at 11:00 but could not go to sleep for more than an hour, which is unusual.

Feb. 26, 6 gr. sugar. A little nervous all day and some pain in the back of my head. Slept better than the night before, but not so soundly as usual. About 7 hrs.

Feb. 27, 6 gr. caffein. Tense feeling in back of head all morning. Felt better during the middle of the day, but extremely nervous during the last period, with weakness in arms. Also choking sensation in throat. Slept very lightly and brokenly for about 7 hrs. Extremely nervous all night.

Feb. 28, 6 gr. sugar. Have felt some better to-day than yesterday but not quite normal. A little nervous all day. Slept better than previous night, but not so well as usual, for about 7 hrs.

March 1, 6 gr. caffein. Some pain in back of head during early morning. Very nervous from 12:00 to 1:00 with choking sensation in throat. Felt better at the 3:00 o'clock hour but a little nervous during the latter part of the day, due, I think, to an attack of nervousness on the part of another subject. Retired at 10:30, but was so nervous and wide awake that I could not sleep until after midnight. Tense feeling with some pain in back of head. Slept fairly well for about 6.5 hrs.

March 2, sugar. Some pain in the back of my head during the earlier morning hours, but have felt as well as usual during the rest of the day. (—).

General Result.—The prominent symptoms mentioned by this subject are more pronounced on caffein days than on control days, but curiously occur as often and as markedly before the dose was taken as later. The symptoms that seem to characterize the periods after the caffein dose are choking sensation, hot head and cold extremities, nervousness and weakness in arms, which symptoms do not especially characterize the post-caffein period until the 4 and 6 gr. amounts are reached. Sleep disturbance is not clearly present until after the 6 gr. dose is given, where it is apparent.

Subject 10, M., 28, 157, Occasional User, Squad IV

Feb. 10, 1 gr. sugar, mid afternoon. Felt as usual all day. Slept worse than usual for no apparent reason. 6 hrs. sleep.

Feb. 11, 1 gr. caffein, as above. Felt as usual. Slept better than usual. 8.5 hrs.

Feb. 12, 1 gr. sugar. Felt and slept as usual. 7.5 hrs.

Feb. 13, 1 gr. caffein. Felt and slept as usual. 7.5 hrs.

Feb. 14, 2 gr. sugar. Felt as usual. Slept better than usual. 8 hrs.

Feb. 15, 2 gr. caffein. Felt and slept as usual. 7 hrs.

Feb. 16, 2 gr. sugar. Felt and slept as usual. 7.5 hrs.

Feb. 17, 2 gr. caffein. Everything as usual. 7 hrs.

Feb. 18, 3 gr. sugar. Everything as usual. 8 hrs.

Feb. 19, 3 gr. caffein. Everything as usual. 7.5 hrs.

Feb. 20, 3 gr. sugar. Felt as usual. Slept poorly for 6 hrs.

Feb. 21, 3 gr. caffein. Felt as usual. Slept worse than usual, 5.5 hrs.

Feb. 22, 4 gr. sugar. Everything as usual. Slept 8 hrs.

Feb. 23, 4 gr. caffein. Felt worse than usual since 2:00 P.M. Have had a dizziness in the head and arm is quite nervous. Slept about as usual for 7 hrs.

Feb. 24, 4 gr. sugar. Everything as usual. Slept 8 hrs.
Feb. 25, 4 gr. caffein. Felt worse than usual. Experienced nervousness and dizziness, which began about 2:15 P.M. Slept as usual, 7.5 hrs.
Feb. 26, 6 gr. sugar. Felt and slept as usual, 7 hrs.
Feb. 27, 6 gr. caffein. Feel worse than usual. Have had a severe headache since about 3:00 P.M. Slept worse than usual on account of headache. 3 hrs.
Feb. 28, 6 gr. sugar. Felt and slept about as usual. 7 hrs.
March 1, 6 gr. caffein. Felt as usual. Never slept any. I know no cause, just sleepless.
March 2, sugar. About as usual.

General Result.—The introspective reports show no caffein influence up to the time of the 4 gr. doses. At this point nervousness and dizziness are reported. No sleep impairment. After 6 gr. caffein doses headache is reported and there is marked sleep impairment.

Subject 11, F., 27, 110, Abstainer, Squad IV

Feb. 10, 1 gr. sugar, mid-afternoon. Subdued headache till after lunch. Rest of day as usual. Slept 8.5 hrs., more soundly than usual.
Feb. 11, 1 gr. caffein, as above. Felt as usual till afternoon. Had slight headache, felt irritable but frisky. No desire to rest as I usually do for half hour after 1:00 o'clock. Slept as usual. 8 hrs.
Feb. 12, 1 gr. sugar. Felt as usual all day. Slept as usual. 8 hrs.
Feb. 13, 1 gr. caffein. As usual all day except for slight headache in early afternoon. Found it hard to sleep. Lay awake for not less than 1 hour. Awoke alert but tired. About 7 hrs.
Feb. 14, 2 gr. sugar. As usual all day except for sleepiness. Slept as usual, for about 8.5 hrs.
Feb. 15, 2 gr. caffein. Felt as usual till 2:00 P.M. Felt then confused and faint a few minutes, then the feeling passed away. But had intermittent returns followed by palpitation of heart during afternoon. Sensations such as follow shock of some sort. Slept 9.5 hrs. deep, dull sleep, not as usual, felt ill all evening, was feverish and shaky, had sensations of sinking during the night.
Feb. 16, 2 gr. sugar. Felt weak and ill all morning. Afternoon better, but still shaky. Some palpitation of heart and dull headache after 2:00 P.M. Severe headache in evening. Slept more soundly than usual, for 9 hrs.
Feb. 17, 2 gr. caffein. Felt somewhat duller than usual during the morning. Headache gone. Especially brisk about 3:00 P.M. Sinking sensations mildly felt about 5:00. Seemed to be intermittent. As well as usual in evening. Slept as well as usual, 8 hrs.
Feb. 18, 3 gr. sugar. Felt and slept as usual. 8 hrs.
Feb. 19, 3 gr. caffein. Felt shaky about 3:00 P.M. This continued off and on until 5:00. No feeling of illness. As usual during evening. Slept as well as usual for 8 hrs.
Feb. 20, 3 gr. sugar. Felt as usual all day. Slept better than usual, 9 hrs.
Feb. 21, 3 gr. caffein. Felt as usual till afternoon. Was confused from 2:00 to 3:00. Noticed some muscular trembling during afternoon, slept poorly for about 7 hrs. Exciting dreams.

Feb. 22, 4 gr. sugar. As usual till noon. From about 1:30 to 3:00 felt excitable. Heart beat very fast. Felt tired after 4:00, but otherwise as usual. Headache during evening. Slept more soundly than usual. 8 hrs.

Feb. 23, 4 gr. caffein. Felt as usual all morning. Very drowsy about 1:00 and unusually stupid. Went out of doors about 2:00 and felt as usual till the 3:10 test, then noticed unusual alertness. Continual overflow of spirits till 4:00. Then I noticed rapid heart beating which felt uncomfortable. Sudden perspiration followed by depression and apprehension. Felt shaky at 5:30, but as usual otherwise, and no sensations of illness or discomfort. Felt very irritable all evening. Calculated on 8 hours' sleep, but was wakeful and slept more lightly than usual, waking often.

Feb. 24, 4 gr. sugar. Morning headache. Felt tired and irritable (worse than usual). As usual all rest of day, except for slight headache in early afternoon and unusual sleepiness. Slept 8 hrs. more soundly than usual.

Feb. 25, 4 gr. caffein. Felt as usual till about 11:00 o'clock. Suddenly felt dizzy and stupid. Was decidedly dizzy for over an hour. Had no ambition to move or think till about 2:00. Gradual rise of spirits till 4:00, then a period of exuberance, of good feeling. Fanciful ideas rampant. Had three sudden attacks of perspiration. Gradual decrease of exhilaration but continued sensations such as felt after shock. Trembling of knees and hands. Uncertainty as to truth of ideas, so feel cautious. Slept as usual for 8 hrs.

Feb. 26, 6 gr. sugar. Felt as usual except for faint headache and dullness. Dull feeling passed away about 4:00 P.M. Severe headache in evening. Could not sleep first part of night and was wakeful during the remainder.

Feb. 27, 6 gr. caffein. Felt somewhat dull and had mild headache until about 3:00 P.M. Was greatly elated about 3:30. After 4:00 felt quivering of muscles in arms and shaking of knees. Sudden perspiration once. Mental confusion noticed from 4:00 to 5:00, after that sharp headache. Violent headache after dinner. Excitement subsided and was followed by deep mental depression and lack of energy. Slept as usual for 8 hrs.

Feb. 28, 6 gr. sugar. Felt as usual till about noon, after which I had a dull headache which continued till about 6:00 P.M. Was unusually stupid during evening. Slept 8.5 hrs., as usual.

March 1, 6 gr. caffein. Felt stupid all morning but otherwise as usual. Was exceedingly sleepy from noon till about 1:30. Had dull headache from 11:00 to about 2:00. Began to feel excited about 2:30 and increasingly happy for an hour. Gradual decrease of excitement after 4:00 o'clock. Felt only slightly shaky at 5:30.

March 2, (—) Was excused from the day's work.

General Result.—The symptoms headache, sleepiness in day and sleeplessness at night, excitableness and heart palpitation, alternating irritability and dullness, mentioned so frequently in this report are on the whole as characteristic of sugar days as of caffein days. (See February 10, 14, 16, 22, 24, 26, and 28.) It is however true that the minutely introspective tendency found in the part of the report given here does not characterize the daily records of the first week of the experiment during which only sugar doses were administered, although restlessness, frantic dreams and daytime lassitude are mentioned. But that these symptoms were more pronounced

on caffein days is obvious from the greater detail found in the reports on those days and from the greater amount of space taken for their description.

The attacks of perspiration, the dizziness, muscular quivering, the feeling of briskness and exhilaration, and the feelings of apprehension and distrust seem to be peculiar to caffein days only, and are present after doses of 2 gr. and over.

Subject 16, M., 24, 174, Regular User

Feb. 10, 1 gr. sugar, mid-afternoon. As usual except for little cold in head. Slept better than usual for 7.25 hrs.

Feb. 11, 1 gr. caffein, as above. Same as usual except for cold. Slept better than usual, 7 hrs.

Feb. 12, 1 gr. sugar. Felt all right until within an hour, when I felt slightly "dippy," good deal the same "weakish" feeling, as if I had smoked too long. 6.75 hours' sleep, better than usual.

Feb. 13, 1 gr. caffein. All right except cold in head. Sleep better than usual, 6.75 hrs.

Feb. 14, 2 gr. sugar. Normal. Sleep (7.75 hrs.) poorer than usual.

Feb. 15, 2 gr. caffein. Normal. A little stale mentally. Sleep better than usual, 7.5 hrs.

Feb. 16, 2 gr. sugar. Felt worse than usual. Sleep better than usual, for 7.75 hrs.

Feb. 17, 2 gr. caffein. All right. In fact buoyant until 5:30, since which time I have had dull headache. 7.75 hours' sleep, better than usual.

Feb. 18, 3 gr. sugar. Same as usual. Head somewhat dull in latter part of day. 7.75 hours' sleep, good as usual.

Feb. 19, 3 gr. caffein. As usual in morning. Headache between 2:30 and 3:30. 7 hours' sleep, poor, a herd of nightmares.

Feb. 20, 3 gr. sugar. Duller than usual. Headache late in P.M. Stomachache all A.M. Sleep better than usual, 7.5 hrs.

Feb. 21, 3 gr. caffein. As usual to-day. Sleep (7.5 hrs.) better than usual.

Feb. 22, 4 gr. sugar. Dull headache, particularly hard in P.M. Sleep 6.5 hrs. better than usual.

Feb. 23, 4 gr. caffein. As usual this A.M. Better than usual from 2:00 to 3:00 P.M. From then until 5:00 nervous tremors as at end of race. Sleep better than usual, 7.5 hrs.

Feb. 24, 4 gr. sugar. Everything better than usual. 7.5 hrs.

Feb. 25, 4 gr. caffein. Better than usual. Shaky the last half hour. 7.5 hours, better than usual.

Feb. 26, 6 gr. sugar. As usual until late this P.M., when head ached for a couple of hours. 9 hours' sleep, worse than usual.

Feb. 27, 6 gr. caffein. As usual until 4:00 P.M., when better than usual. But at 5:30 felt sickish and decidedly shaky all over. Sleep worse than usual, for 7.25 hrs.

Feb. 28, 6 gr. sugar. As usual. Have a cough. 7.5 hours' ordinary sleep.

March 1, 6 gr. caffein. As usual this A.M. But have been bothered lately with indigestion. Felt stimulated this P.M. Had nervous tremors from head to foot. Some drowsiness. 7 hours' sleep, worse than usual. Nightmares. Awakened at 1:15.

March 2, sugar. As usual. Cough still present.

General Result.—No difference between caffein days and control days up to time of 4 gr. doses. After 4 and 6 gr. doses of caffein shakiness and tremor present. No signs of sleep disturbance for amounts less than 6 gr., after which, sleeplessness.

Subject 8, M., 24, 144, Regular User, Squad II

Feb. 10, 1 gr. sugar, 10:30 A.M. Feeling as usual, except for a slight headache, which has been felt from time to time all day. Slept as usual for about 8 hrs.

Feb. 11, 1 gr. sugar, as above. Feeling as usual. Sleep not quite as good as usual. 8 hrs.

Feb. 12, 1 gr. caffein, as above. As usual, except for slight headache, which may be due to a cold. Slept as usual for 7.5 hrs.

Feb. 13, 1 gr. caffein. As usual, except for headache just before lunch. Did not sleep as well as usual. 7 hrs.

Feb. 14, 1 gr. caffein. As usual, except for slight headache at close of day. Did not sleep quite as well as usual. About 7.5 hrs.

Feb. 15, 2 gr. sugar. Feeling as usual. Did not sleep as well as usual. About 6.5 hrs.

Feb. 16, 2 gr. sugar. Feeling as usual, except for slight headache just before noon. Slept as usual, for about 7.5 hrs.

Feb. 17, 2 gr. caffein. As usual, except for slight headache between 12:00 and 1:00 o'clock. Slept as usual. 7.5 hrs.

Feb. 18, 2 gr. caffein. Felt as usual. Did not sleep as well as usual. I awakened several times during the night. About 7 hrs.

Feb. 19, 2 gr. caffein. Felt and slept as usual. 8 hrs.

Feb. 20, 3 gr. sugar. Felt and slept as usual. 7.5 hrs.

Feb. 21, 3 gr. sugar. Felt and slept as usual. 7.5 hrs.

Feb. 22, 3 gr. sugar. Felt and slept as usual. 8 hrs.

Feb. 23, 4 gr. caffein. As usual, except for a headache which has recurred from time to time since about noon. Slept not quite so well as usual, for about 7.5 hrs.

Feb. 24, 4 gr. caffein. As usual, except for very *slight* headache during the early afternoon for about 3 hrs. Did not sleep as well as usual. About 6 hrs.

Feb. 25, 4 gr. caffein. Feeling as usual to-day, except that I have felt a trifle stupid. Slept as well as usual for about 8 hrs.

Feb. 26, 6 gr. sugar. Felt and slept as usual, about 8 hrs.

Feb. 27, 6 gr. sugar. Feeling as usual, except for slight headache between 12:00 and 1:00 and after 5:00 o'clock. Slept as usual, for about 7.5 hrs.

Feb. 28, 6 gr. sugar. Felt and slept as usual. About 8 hrs.

March 1, 6 gr. caffein. Felt as usual until about noon, when I began to feel a dull headache which lasted until about 1:00 o'clock. This returned about 3:00 and has remained ever since. I have been extremely nervous all afternoon and have felt feverish. Did not sleep as well as usual. About 7 hrs.

March 2, sugar. Felt as usual to-day, except for a headache since 3:00 P.M. Headache was not so bad as yesterday.

General Result.—The headache reported by this subject on so many days seems to be chronic, and is present as frequently on control days as on caffein days. (See February 10, 16, 27, and March

2.) But on caffein days the headache is reported as continuing until later in the day than usual. Signs of unusually poor sleep after the 4 and 6 gr. caffein doses. Nervousness and feverishness after the 6 gr. amount only.

Subject 12, M., 24, 160, Regular User, Squad II

Feb. 10, 1 gr. sugar, 10:30 A.M. Felt as usual, slept worse than usual for 7.5 hrs.
Feb. 11, 1 gr. sugar, as above. Felt as usual, slept worse than usual for 6.5 hrs.
Feb. 12, 1 gr. caffein. Felt and slept as usual, 7.5 hrs.
Feb. 13, 1 gr. caffein. Felt and slept as usual, 7.5 hrs.
Feb. 14, 1 gr. caffein. Felt and slept as usual, 7.5 hrs.
Feb. 15, 2 gr. sugar. Felt as usual. Slept better than usual, 7.5 hrs.
Feb. 16, 2 gr. sugar. Had bad headache during day, which was probably due to a bad cold. Especially bad about 1:00 to 4:00 o'clock, but somewhat better by 5:30. Slept as usual, for 7.5 hrs.
Feb. 17, 2 gr. caffein. Slight headache all day, especially bad at 5:30. May have been due to quinine, which was prescribed for my cold. Slept as well as usual, for 7 hrs.
Feb. 18, 2 gr. caffein. About as usual all day, though very nervous at the 12:00 o'clock session. Cause unknown. Slept as usual, for 7 hrs.
Feb. 19, 2 gr. caffein. Felt and slept as usual. 7 hrs.
Feb. 20, 3 gr. sugar. Felt about as usual all day, though better than for the past few days. Am beginning to recover from a cold and have not had any headache such as has been bothering me for the last few days. Slept as usual. 8 hrs.
Feb. 21, 3 gr. sugar. Felt and slept as usual. 7.5 hrs.
Feb. 22, 3 gr. sugar. Felt like a "bone head" all day. My head was dull more than usual. Otherwise all right. Slept as usual, 7.5 hrs.
Feb. 23, 4 gr. caffein. Felt as usual until about 12:00 o'clock. Then I became very nervous for some reason and had great trouble controlling my nerves. This nervousness continued until about 4:30, at which time I began to feel better. By 6:00 I felt almost as well as usual. Cause unknown to me. Slept as usual, 7 hrs.
Feb. 24, 4 gr. caffein. Felt as usual, except at 12:00, when I had a headache, and at 5:30, when I was nervous. Slept as usual, 7.5 hrs.
Feb. 25, 4 gr. caffein. Felt as usual until 12:00, when I became quite nervous and remained so until 6:30. Also had slight headache during the same period. Slept as usual. 6.5 hrs.
Feb. 26, 6 gr. sugar. Felt "dippy" and dull all day, cause unknown, unless weather is to blame. Slept as usual, for 7.5 hrs.
Feb. 27, 6 gr. sugar. Felt better when I got up than usual. Remained so all day. Slept as usual, 7.5 hrs.
Feb. 28, 6 gr. sugar. Felt as usual all day, though I was a little nervous about 5:30. Slept as usual, for 7.5 hrs.
March 1, 6 gr. caffein. Felt as usual until 12:00 o'clock, when I became extremely nervous and remained so until 6:00 P.M. During the same time I had also a fever. Slept worse than usual, 7.5 hrs.
March 2, sugar. Got up feeling worse than usual. Felt dull all day and had a bad headache.

General Result.—No clear difference between control and caffein days up to time of 4 gr. doses. Nervousness and headache follow about 2 hours after the 4 and 6 gr. caffein amounts. No sleep impairment except perhaps after 6 gr. dose of caffein.

Subject 13, M., 22, 175, Regular User, Squad II

Feb. 10, 1 gr. sugar, 10:30 A.M. Felt and slept as usual, 7 hrs.

Feb. 11, 1 gr. sugar, as above. Felt and slept as usual, but awoke with a terrific headache.

Feb. 12, 1 gr. caffein. Felt miserable this morning, with sick headache. Was prescribed calomel. Felt weak and indifferent after this dose. Slept as usual. 7 hrs.

Feb. 13, 1 gr. caffein. Felt very well all day, except for most uncomfortable rumbling and confusion which seems to be going on inside. Slept as well as usual. 7.25 hrs.

Feb. 14, 1 gr. caffein. Felt and slept as usual. 7.25 hrs.

Feb. 15, 2 gr. sugar. Felt and slept as usual. 8.75 hrs.

Feb. 16, 2 gr. sugar. Felt as usual to-day, with exception of slight heaviness this morning. I attribute this to too much sleep last night. Slept more heavily than usual, 6.75 hrs.

Feb. 17, 2 gr. caffein. Felt and slept as usual. 7.25 hrs.

Feb. 18, 2 gr. caffein. Felt and slept as usual. 6.75 hrs.

Feb. 19, 2 gr. caffein. Felt as usual all day with the exception of my eyes. Had them examined and they have been suffering a good deal. This morning I had a kind of headache. Broken sleep and headache in evening. Retired at 8:00 and arose at 6:45.

Feb. 20, 3 gr. sugar. As usual all day. Felt sleepy after dinner at night and retired at 8:30, arising at 6:45. Felt stupid and drowsy.

Feb. 21, 3 gr. sugar. As usual all day. Had a broken sleep from 9:00 to 6:45.

Feb. 22, 3 gr. sugar. Felt a little stupid, otherwise all right. Slept as usual, but only 6.5 hrs.

Feb. 23, 4 gr. caffein. Felt tremendously exhilarated and energetic for about an hour and a half, from 12:00 to 2:00, and since I have been extremely nervous and a trifle unstrung. Took a long time for me to go to sleep, slept as usual then, for 6.75 hrs.

Feb. 24, 4 gr. caffein. Felt as usual all day. Retired at 10:00 with just the beginnings of a cold. Took quinine and hot lemonade, and had a heavy sweat. Slept as usual and feel bully this morning.

Feb. 25, 4 gr. caffein. Felt as usual until about 1:00 P.M. and then began to feel very nervous. Felt nervous until 3:00 and had griping pains in abdomen. Still slightly nervous (6:30). Slept as well as usual, for 7:75 hrs.

Feb. 26, 6 gr. sugar. As usual all day. Slept more heavily than usual, for 7.75 hrs.

Feb. 27, 6 gr. sugar. As usual all day. Played three games of handball and felt extremely tired up till about 3:00. No pains or nervousness. Slept as usual, for 8.5 hrs.

Feb. 28, 6 gr. sugar. As usual all day. Slept as usual, but with queer and very unusual dreams. 7.5 hrs.

March 1, 6 gr. caffein. Felt as usual up to 12:00 or so. Felt extremely nervous, shaky physically, ever since. Not so nervous at time of writing (6:30), but very irritable. Slept as well as usual, for 6.75 hrs.

March 2, sugar. Feel miserable. Developed a sick bilious headache around 1:00 P.M. and it has been increasing in intensity steadily. No relief by 6:30 P.M.

General Result.—No effect up to time of 4 gr. doses of caffein. Nervousness and irritability follow these and the 6 gr. dose. No report whatever of sleep impairment after caffein. Stomach pains mentioned after one of the 4 gr. doses.

Subject 2, F., 38, Regular User. Worked Alone

Feb. 10, sugar, 8:30 A.M. Been dreaming of typewriting. Recovering from a cold. Feel tired and have headache and pain or ache in upper part of spine. Slept as usual. Strange dreams. 7.5 hrs.

Feb. 11, sugar, as above. Seem to be more nervous than usual. Did not have good control. Cold better. Not so much aching and not so tired. Slept about as usual, perhaps a little more wakeful. 7 hrs.

Feb. 12, sugar. Woke feeling well, except for cold, which is better. Felt the best physically of all days so far. Head felt a little full during the 3:10 period. Slept as usual, for about 7 hrs.

Feb. 13, 1 gr. caffein, as above. Felt best of any day. Cold about same. Did best work yet. Slept unusually well for about 7 hrs.

Feb. 14, 1 gr. caffein. Felt well all day, but tired at night and a little discouraged. Slept fairly well for about 7 hrs.

Feb. 15, 2 gr. sugar. Felt tired and languid all day, with slight headache, increasing a little toward night. Slept as usual, 7 hrs.

Feb. 16, 2 gr. caffein. Slight headache in morning disappeared by noon. Aside from cold, which is better than yesterday, have felt very well. Slept about as usual for 7.5 hrs.

Feb. 17, 2 gr. sugar. Felt some dullness and lassitude as is usual on such dark rainy days. Otherwise have felt very well. Slept as usual. About 7.5 hrs.

Feb. 18, 3 gr. caffein. Felt pretty well this A.M.; slight headache developing towards night (catarrhal) probably due to the damp weather. Slept very soundly for about 6 hrs., and less soundly for 1 hour more.

Feb. 19, 3 gr. sugar. Felt pretty well through the day, except that the work seemed to be an effort. Tired and somewhat discouraged when night came. Slept very poorly for about 6 hrs. Unusually nervous and worried.

Feb. 20, 3 gr. caffein. Have felt dispirited and out of harmony somewhat all day—perhaps due to lack of sleep—otherwise well. Slept about as usual for 7.5 hrs.

Feb. 21, 4 gr. sugar. Did not feel very well through the day, but better to-night. Slept unusually well for about 8 hrs.

Feb. 22, 4 gr. caffein. Felt fine all day, as is usual in good weather. Slept as well as usual for about 7 hrs.

Feb. 23, 4 gr. sugar. Felt as usual all day. Slept as usual, for 7.5 hrs.

Feb. 24, 4 gr. caffein. Felt well all day. Did not sleep nearly so well as usual, not more than 3 or 4 hrs. Seemed to be nervous. Heart thumping part of the time and then very faintly.

Feb. 25, 4 gr. sugar. Felt as well as usual. Slept as usual for 7 hrs. Felt tired in the morning, probably due to lack of sleep the night before and to the damp cloudy day.

Feb. 26, 4 gr. caffein. Slight headache most of the day, with some aching in back. About as usual in soft damp weather. Slept fairly well for about 6 hrs.

Feb. 27, 6 gr. sugar. Felt about as usual, except tired from lack of sleep. Slept pretty well for about 7 hrs. Awoke with headache, due perhaps to cold.

Feb. 28, 6 gr. caffein. Headache most of day. Eyes felt weak and watery. Hands cold most of the day. Felt better toward night. Slept rather brokenly for about 7 hrs.

March 1, 6 gr. sugar. Felt cold all day, arms stiff, could not relax much. Slept very well for about 7 hrs.

March 2, 6 gr. caffein. Felt well most of the day. Slight headache part of the forenoon. (No record of sleep for this day.)

General Result.—Up to the time of 4 gr. doses there is no clear difference between caffein days and control days. After doses larger than this, headache is present, and disturbed sleep. Headache, nervousness, tired and discouraged feeling about as prominent on control days as on caffein days.

Final Statement of Results for All Squads

Allowance must be made for the tendency to headache and nervousness reported even by members of the control squad (see especially subjects 1, 7 and 15). The strain involved in the repeated completion of the series of tests at the highest possible level of performance was considerable. Thus the cancellation test produced such great eye strain on the part of one member of the control squad that it was found necessary to excuse him permanently from this test. Most of the subjects reported more or less strain directly traceable to the strenuous character of the tests themselves. Consequently only such symptoms can be securely taken to indicate caffein effect as are clearly present on caffein days only or are unusually prominent on those days, as compared with the control days. Tendency to headache, nervousness, dizziness, feverishness and occasional sleeplessness are distributed in a fairly uniform way throughout the reports of the control squad. Bearing these facts in mind, the following seems to be a fair statement of the influence of caffein on the general health and feeling of well-being in the case of the subjects participating in the present experiment.

Squad II. (weights 144, 160 and 175), taking pure caffein alkaloid doses three days in succession at 10:30 A.M., *without food-substance.*—No effect up to the time of the 4 gr. doses. After 4 and 6 gr. amounts, nervousness, feverishness, headache, irritability and disturbed sleep. Much the same thing may be said of Subject 2, who took doses at 8:30 A.M., working independently of the squads.

Squad III. (*weights 130, 159, 193*), *taking pure caffein alkaloid on alternate days, with increasing doses, with the mid-day lunch.*—No sleep impairment except in the case of the woman after 6 gr. Nervousness and heartburn or stomach pains after doses of 3 gr. or over. Dizziness and headache after 6 gr. amounts.

Squad IV. taking the doses on alternate days in the mid-afternoon on an empty stomach.—Men subjects (weights 157, 174), no influence up to time of the 4 gr. doses. For larger doses, nervousness and dizziness or headache. Sleeplessness after 6 gr. amounts only.

Women subjects (weights 105, 125, 110), dizziness or lightheadedness, attacks of perspiration, numbness or coldness of extremities, nervousness, drawn feeling in throat and head, and sleeplessness unusually prominent in the case of *the two slightest subjects* after doses larger than 2 or 3 gr. In the case of the heaviest of the three, the symptoms do not appear in any unusual degree until after the 4 or 6 gr. amounts, as in the case of the men. The apparent sex difference found with this squad is probably entirely a function of body weight.

The subjects quite uniformly report improvement in health, spirits and general efficiency at the close of the experiment. This is perhaps due to the regular régime of life followed during the 40 days. Those who had given up the use of caffein-containing beverages during the experiment and for several days previous to its beginning do not report any craving for the drinks as such, but several expressed a feeling of annoyance at not having some sort of a warm drink for breakfast. Two subjects report a gain in weight, two a loss, and the rest either report no change or are unable to state.

The two principal factors which seem to modify the degree of the caffein influence are *body weight* and the *presence of food* in the stomach at the time of the dose. For more detailed study of the influence of caffein on the quality and amount of sleep, see the special chapter dealing with those points. There is a close correlation between the two sets of results (sleep and general health).

CHAPTER XV

Conclusion

The results for each test have been briefly summarized at the close of the chapters. No attempt need be made to restate these conclusions here except perhaps by way of a schematic review of all the tests. Such a review is presented in the following tabular summary. Such a summary is of course wholly inadequate to express the significant facts which the various chapters have brought forward. Its chief interest comes from the assemblage of the various tests in groups, the groups being roughly designated by the psychological process or function which is especially prominent in the performance of the tests included in the group. It is clear at once that the caffein influences all the tests in a given group in much the same way. The effect on motor processes comes quickly and is transient. The effect on higher mental processes comes more slowly and is more persistent. Whether this result is due to quicker reaction on the part of motor nerve centers, or whether it is due to a direct peripheral effect on the muscle tissue, the pure psychologist can hardly be expected to know. Physiological experiment, however, seems to indicate that caffein has a direct effect on the muscle tissue, and that this effect is fairly rapid in appearance. The physiology of absorption also explains the fact that the presence of food substance in the stomach retards and reduces the caffein influence. The dependence of the amount of the caffein influence on the body weight of the individual has already been explained in terms of the amount of the substance ingested per unit of tissue affected.

One of the most interesting facts shown by these experiments is the complete absence of any traces of secondary depression or of any sort of secondary reaction consequent upon the stimulation which is so strikingly present in many of the tests. Rivers' conclusion, already referred to, that "caffein increases the capacity for both muscular and mental work, . . . without there being any evidence, with moderate doses, of reaction leading to diminished capacity for work," is thoroughly confirmed by the results of all the present experiments. This result is quite in contrast with the secondary reaction said to follow stimulation by such a drug as strychnine. It must be said that our present knowledge concerning the precise mode

of action of drugs on nervous tissue is very inadequate. That the increased capacity for work is produced is clearly demonstrated. That this result is a genuine drug effect, and not merely the effect of excitement, interest, sensory stimulation, expectation or suggestion, the carefully controlled tests here reported prove beyond any possible doubt. But whether this increased capacity comes from a new supply of energy introduced or rendered available by the drug action, or whether energy already available comes to be employed

SCHEMATIC SUMMARY OF ALL RESULTS

St. = Stimulation. 0 = No effect. Ret. = Retardation

Process	Tests	Primary Effect: Small Doses	Medium Doses	Large Doses	Secondary Reaction	Action Time, Hours	Duration in Hours
Motor speed	1. Tapping	St.	St.	St.	None	.75–1.5	2–4
Coordination	2. Three-hole	St.	0	Ret.	None	1–1.5	3–4
	3. Typewriting						
	(*a*) Speed	St.	0	Ret.	None	Results show only in total days' work.	
	(*b*) Errors ...	Fewer for all doses.			None		
Association	4. Color-naming ..	St.	St.	St.	None	2–2.5	3–4
	5. Opposites	St.	St.	St.	None	2.5–3	Next day
	6. Calculation	St.	St.	St.	None	2.5	Next day
Choice	7. Discrimination-reaction time ..	Ret.	0	St.	None	2–4	Next day
	8. Cancellation ...	Ret.	?	St.	None	3–5	No data
	9. S-W illusion ...	0	0	0			
General	10. Steadiness	?	Unsteadiness		None	1–3	3–4
	11. Sleep quality ..	Individual differences depending on body weight and conditions of administration.				?	
	12. Sleep quantity .						
	13. General health .						

more effectively, or whether the inhibition of secondary afferent impulses is eliminated, or whether fatigue sensations are weakened and the individual's standard of performance thereby raised, no one seems to know. The interpretation is obscure but the facts are plain.

The widespread consumption of caffeinic beverages under circumstances in which and by individuals for whom the use of other drugs is stringently prohibited or decried seems to be justified by the results of experiment. But it should be emphasized that the results of the investigation here reported bear only on the more or less immediate effects of caffein on performance. It is true that the investigation as a whole covered a period of 40 days, and that in the intensive experiment the effect of single doses was traced for a period of 3 days. But the results can not be carried over bodily to the

question of the continuous use of the drug. One can only assume that if the constant use of caffein in moderate amounts would prove deleterious, some indication of such effect would have shown itself in the careful study of performance in tests covering a wide range of mental and motor processes, a wide range of doses and of individuals, and of time and conditions of administration. Nor can anything be said, on the basis of these results, concerning the physiological or neurological effect of caffein, except in so far as integrity of structure can be inferred from unimpaired function or performance.

It should be further pointed out that the quantitative results of this investigation of the influence of caffein in its pure form can not be directly compared with the action of its citrated form, which is only half caffein, the remainder being citric acid which itself has a demonstrable action on nerve and muscle tissue. Much the same thing is true of the action of tea, coffee, and other caffeinic beverages, which contain a variety of other substances which may be supposed to enhance or neutralize or otherwise modify the effect of the caffein content.[1] Many of the results commonly attributed to these beverages undoubtedly come, in so far as they can be demonstrated at all under controlled conditions, from these non-caffein ingredients.

[1] The average cupful of hot tea (black, 5 fluid ounces) contains about 1.5 gr. of caffein. About the same amount is present in the average after-dinner cup of black coffee (2 fluid ounces). An average glass of cold green tea (8 ounces exclusive of ice) contains about 2 grains, while an average cupful of coffee with hot milk (5 ounces, three fifths coffee and the rest milk) contains about 2.5 grains of caffein.